Johnson:
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BEHAVIOR MONOGRAPHS

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Edited by JOHN B. WATSON
The Johns Hopkins University

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HARRY MILES JOHNSON

Dissertation submitted to the Board of University Studies of the Johns Hopkins University in conformity with the requirements for the degree of Doctor of Philosophy

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I. PITCH-DISCRIMINATION[1]

HISTORICAL

Several reports of experimental tests on the audition of the dog have been published. Most of them have been made by physiologists, who were interested not so much in the degree of the animal's discrimination as in the localization of the cerebral centers which govern it.

Pavloff's[2] school (notably Selionyi[3]) have attempted the determination of the dog's sensitivity to differences of pitch, by the saliva-reflex method. Yerkes and Morgulis[4] have given a comprehensive description in English of this method. Some of the most important points in their article are set forth below.

The saliva-reflex (secretion of saliva) occurs under two strikingly different conditions: when the glands are stimulated by the specific (chemical) stimuli for secretion; and when the animal is presented with visual, olfactory, auditory or other stimuli, which have been concomitants of direct stimuli of the salivary grands. "The environment of the dog may be said to consist of two sets of properties, the essential and non-essential." Properties essential for a given reaction are those characteristics of an object which "regularly and definitely determine the reaction of the organism;" non-essential properties of the object are "those which only in a highly variable and inconstant manner condition the reaction." The chemical property of food, whereby it acts on the receptors of the mouth of the dog, is an example of the essential class; the brightness, color, etc., are examples of the non-essential properties. Reflex responses to "essential" properties are called "unconditioned" reflexes;

[1] From the psychological laboratory of the Johns Hopkins University.

[2] Pavloff, J. P. The scientific investigation of the psychical faculties or processes in the higher animals. *Lancet*, 1906, pp. 911–915..

[3] Selionyi, G. P. Contribution to the study of the reactions of the dog to auditory stimuli. Dissertation. St. Petersburg, 1907. (In Russian.) Method reported by Yerkes and Morgulis, l.c., below.

[4] Yerkes, R. M. and Morgulis, S. The method of Pavloff in comparative psychology. *Psychological Bulletin*, 1909, pp. 257 ff.

those in response to "non-essential" properties are called "conditioned" reflexes.

The following experimental procedure is followed: "A normally active and healthy dog of vigorous salivary reaction having been selected, the duct of one of the salivary glands—the parotid for example—is exposed on the outer surface of the cheek and a salivary fistula is formed. The wound heals completely within a few days and the dog exhibits no signs of discomfort or inconvenience. Those who have used the method insist, indeed, that their animals are perfectly normal." Devices are applied to catch and measure the saliva secreted in different intervals of time.

In the auditory tests the animal is accustomed to being fed at a certain tone or sound until the saliva secretion begins when the sound is made. Unfamiliar sounds do not provoke the reaction. Selionyi reports that discrimination was established by this method between tones only a quarter of a tone different in pitch. Further difference-diminution than this did not produce such marked difference in secretion: if the two tones were very near together in pitch, the "unfamiliar" one provoked a secretory response, but not to such a degree of intensity as did the "familiar" one. If the "familiar" tone was sounded too faintly, however, the reflex conditioned by it was either very weak or else did not appear. If an unfamiliar tone the pitch of which differed very slightly from that of the familiar tone were given just before the familiar one was sounded, the reflex conditioned by the latter was partially inhibited.

Yerkes has remarked that there are several obvious disadvantages attached to this method: "conditioned reflexes" die out with repeated stimulation; the quality of food given conditions a remarkable variation in the flow; and the rate of secretion is conditioned also by the time-interval between stimuli. To this I would add the suggestion that there may be also a tendency to rhythmical change in the rate and quantity of secretion. Moreover, Selionyi tells us that the animal was affected by the "kind of movements" made by the experimenter, who had to be careful neither to move too quickly nor to hold himself too rigidly quiet. As slight changes of posture are very often involuntary there is room for doubt whether they

were eliminated. That the method itself can be put to practical use and be so improved as to become wholly reliable has not yet been demonstrated. In any case there remains the question whether the results obtained by this method would show the relative importance of the animal's sensitivity to given stimuli, as referred to his behavior under normal conditions. A change in the auditory stimulus great enough to occasion change in the saliva-reflex conditioned by it may be much too slight to occasion a change in the so-called voluntary reactions; or the contrary may be true.

In 1891, Goltz[5] removed the entire cerebrum from one dog, which lived for over eighteen months thereafter under constant observation in the laboratory. At very high tones or at very loud noises the animal would prick its ears or turn its head. If the stimulus was very intense it would even strike at its ear with the forefoot "as if it wished to stop its ear." From these reactions, Goltz denied that the animal was "totally deaf." Munk calls attention to the possibility that the animal was reacting to pain-stimuli and not to tone or even to noise. This suspicion seems to be well grounded.

Munk[6] himself made some experiments with dogs, using nine pipe-organ tones about an octave apart, and taking the animals' ear-, head- and body-movements as criteria of audition. If these movements were no longer made after operation on the cerebrum, he assumed that deafness has been produced. Having extirpated different regions of the supposed auditory center from trained dogs, and having compared the motor reactions following the operation with the former responses of the dogs, Munk concluded that the dog's center for tone lies in the temporal lobe; that perception of the high tones is conditioned by the function of the anterior portion of the center, while that of the deeper tones depends on the activity of the posterior region. While these results are extremely interesting, and valuable if it can be established that the animals reacted only to auditory stimuli, yet the behavior method is open to the criticism that it cannot be used to determine the animal's discrimination between stimuli. Kalischer, whose work we shall pres-

[5] Described by MUNK, H. Functionen von Hirn und Rückenmark. Berlin, 1909. Article Ueber den Hund ohne Grosshirn. 1894. Pp. 137 ff.

[6] MUNK, H. Ueber die Functionen der Grosshirnrinde. Berlin, 1890. Pp. 113 ff.

ently take up, asserts also that dogs which after operation made no such responses as Munk chose as criteria, could yet discriminate accurately between tones and between chords. Assuming that Kalischer's dogs were reacting only to auditory stimuli—of which fact there is room for doubt—this objection to Munk's method would be fatal.

Kalischer[7] reported in February, 1907, some experiments which he had carried on for the purpose of testing the relation between the temporal cortex and tone-perception. He purposed particularly to test experimentally the conclusion of Munk regarding the specialized function of this area.

The number and ages of the animals used is not reported, but they were chosen from at least six different breeds. Kalischer trained his dogs to take food upon the sounding of a given tone and to refrain from seizing it upon the sounding of any other. The food was either held in the experimenter's hand before the dog or laid on a chair by which the experimenter stood.

The tones were sounded first on the organ used by Munk, which contained nine pipes—the octaves from C_1 to c^7. Later he substituted the piano and still later the harmonium, finding the latter best suited to his purposes.

The daily tests on each animal were arranged about as follows: Kalischer struck a certain tone and as long as it sounded fed the animal bits of meat from the hand. In the first two daily experiments he sounded only the one food-tone, so that he might accustom the animal to being fed at the sound. "From about the third day on," he says, "I struck now and then another tone, and while it sounded I held the bit of meat in the closed hand, so that the animal could not reach it and had to content himself with sniffing at my hand." Then he caused the food-tone to sound again and fed the animal bits of meat, one after the other as long as the sound lasted. In all his tests thereafter, he "struck besides the food-tone other 'Gegentöne' and at the latter prevented the animal from seizing the food."

Kalischer does not say in what order the respective stimuli were given. The expression "now and then (zwischendurch)" is far less definite than one should desire or expect. As previous

[7] Kalischer, Otto. Zur Function der Schlaeffenlappens des Grosshirns. Eine neue Hörprüfungsmethode bei Hunden; zugleich ein Beitrag zur Dressur als physiologischer Untersuchungsmethode. *Sitz. der K. Preuss. Akad. d. Wisschftn.* 1907, pp. 204 ff.

experimenters[8] have pointed out, and as appears in the behavior of every animal which I have used in discrimination tests, the animals quickly form the habit of reacting in a certain rhvthm or in a regular order or by taking a certain position, regardless of the stimulus presented. These "position habits" and rhythmic choices are exceedingly hard to break up. If the order of presentation of the stimuli happens to coincide with or approximate the habitual order adopted by the animal, a very high record, or one even of perfect accuracy may be obtained when the animal really has not been affected by the stimulus.[9] And indeed nothing is easier than for the experimenter to fall into a rhythmic order of presenting the stimuli unless he determines beforehand a chance order of presentation for each day's series of trials. This question should be borne in mind while Kalischer's results are being considered, for we shall have occasion to consider it later.

A further criticism may be made at this point. Kalischer writes that the harmonium suited his purposes better than the piano and some other instruments, because with the harmonium it is possible to sustain the tone as long as is desired—or until the animal has reacted. Now, it should not be forgotten that the duration of the stimulus may easily become the basis of the animal's choice. In such an experiment as Kalischer's, when the dog is to react to one tone and is under penalty to inhibit reaction to the others, reaction may not occur immediately following the stimulus. If the animal is timid reaction will probably be delayed. There is a strong temptation, which I have experienced, to sustain the stimulus-tone a little longer if the animal does not react properly or promptly, so as to give him full opportunity to hear the tone. On the other hand the experimenter is likely to become content quickly if the animal does not react immediately to a "Gegenton" and damp the stimulus; whereas the animal might have reacted had the tone been held a little longer. Rothmann, whose work we shall presently discuss[10] tells us that in his experiments the duration of the stimulus-tone was a disturbing factor, although he

[8] c. f., Yerkes, R. M. The Dancing Mouse, p. 111.

[9] An actual record of one of my animals, nicely illustrating this point is shown on page 52.

[10] Rothmann, Max. Ueber die Ergebnisse der Hörprufung an dressierten Hunden. *Arch. f. Physiol.*, 1908, pp. 103 ff.

reports no precautions against it, and does not consider it in interpreting his data. He says: "After three weeks (of training) the dogs reacted with perfect accuracy; only now and then, at a tone of abnormally long duration, a false reaction occurred." [11] Again, speaking of animals bereft of one posterior corpus quadrigeminum, which were hardly disturbed by the operation: "If the tones were sounded for a somewhat longer time, then the dogs came at every tone." [12] To guard against disturbance from this source, care should be taken to make the duration of all stimuli the same at every presentation. Before Kalischer and Rothmann assumed that their animals were discriminating only the pitch of tones, they ought to have shown in control tests that their animals would not react to a "Gegenton" no matter how long was its duration.[13]

Kalischer does not tell us how many trials he gave the animals at each daily test, nor how many trials altogether were required to achieve perfection. Data on both of these questions are highly desirable in reports of behavior experiments. He does say in this report, however, that the daily test on each animal lasted not longer than five or six minutes. In reporting another experiment of similar character he tells us that about fifteen minutes were required to give eight to ten trials[14]. This tallies with the writer's experience. An animal should not be worked much faster than this, as the risk of its becoming "inattentive" is too great. But it is evident that the stimulus cannot be presented over three to five times in the five or six minutes which Kalischer allowed for a daily series. The possibility of varying the order of presentation of food-tone and "Gegentöne" is also greatly limited by the brevity of the series. For this reason it is doubtful whether the animal is given a fair test of discrimination. An animal making random choices only may chance to make most of the first three or four of a series correctly, and yet be unable to maintain accuracy through a varied series of ten to twenty trials. On the other hand, some

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[11] Loc. cit., p. 107.

[12] Loc. cit., p. 109.

[13] It may be said here that it is quite possible to make tests of the dog's sensitivity to mere duration-difference of auditory stimuli. The results of such an investigation should prove very interesting.

[14] Kalischer, Otto. Weitere Mitteilung ueber die Ergebnisse der Dressur als physiologischer Untersuchungsmethode auf den Gebieten des Gehör—Geruchs- und Farbensinns. *Arch. f. Physiol.*, 1909.

of my animals, after making three or four wrong choices successively have finished a series of fifteen trials correctly.

To return to Kalischer's procedure: He says, "From the fifth or sixth day on, even if I held the bit of meat in the open hand, many animals would no longer attempt to seize it at the 'Gegentöne.' Thus ever more frequently correct reactions ensued." From this point on the animals were "punished by a light blow on the jaw when they snapped falsely after the food."

Some of the animals were taught to take food at high tones —ome at c-2048 d.v.—and others at as low tones as "C_7."[15] The "Gegentöne" chosen at first were those lying as far as possible from the food-tone. After the animals had learned to inhibit reaction to these, others nearer the food-tone were chosen. Kalischer says that the greater the difference between food-tone and "Gegenton" the more quickly the animal learned to discriminate; but that it was possible and not very difficult to train the animal to discriminate between the food-tone and one only a semi-tone removed. We should examine with some care his description of the animals' behavior in the experimental situation, however. "Bei den weitab vom Fresston liegenden Tönen pflegte später der gut dressierte Hund, scheinbar erschreckt, schnell zurückzuspringen, während er bei den näher leigenden Gegentönen *öfter Neigung zeigte, zuzuschnappen,* (italics mine) was sich deutlich an den Kopfbewegungen beobachten liess." Again: "Liess man den Fresston oft hintereinander ertönen, die zunächst prompt nach die Fleischstücken gegriffen hatten, Ermüdungserscheinen geltend." "Die Tiere hörten auf, nach den Fleischstücken zu greifen; und erst wenn man zwischendurch wieder einen der Gegentöne angeschlagen hatte, griffen die Tiere von neuem beim Fresston wieder in gewohnter Weise zu. * * * Auch hier war es von Zeit zu Zeit nötig, zwischendurch einen der Gegentönen erklingen zu lassen."

These remarks indicate that Kalischer regarded his animals as discriminating even though they sometimes did not react to the food-tone and did not inhibit reaction to "Gegentöne." We may then seriously inquire what was the experimenter's criterion of discrimination. How could he know that failure to respond was due to fatigue and is not rather evidence of lack

[15] This is doubtless a misprint: C_1, 64 d.v., is probably meant.

of discrimination? If the reactions and inhibitions are no more definite than this, interpretation of results is extremely unsafe. I have already referred to a day's record made by one of my animals, showing an "accuracy" of 80%, whereas the animal was not being affected by the stimulus. Dependable results cannot be had from less than several fairly long and perfect consecutive daily records, obtained under conditions of control.

A further question: Assuming that the "mental" condition indicated by "scheinbar erschreckt" was legitimately ascribed to the animals, to what may we best consider it due? Since the experimenter was in the room, near the dogs, we are not safe in saying that their "fright" was occasioned by association of only the perceived tone with punishment. The work done by Moll [16] and later by Pfungst [17] and Stumpf on the now famous horse of Herr v. Osten, "*Der kluge Hans*," showed that in a situation of expectant interest it is almost impossible for one to avoid making certain slight, often unconscious and involuntary movements; and it has been demonstrated that animals, hypnotic subjects, gamblers, mediums, and even the most honest laboratory subjects may react unconsciously to such movements, thus accomplishing the deception of the experimenter and sometimes of themselves. It is not proof of actual inhibition of such movements to say as did Shepherd [18] that "care was taken to avoid them." The most important point brought out in the investigation of *Hans* is that the movements are made both unconsciously and involuntarily, and are usually discovered indirectly. In Kalischer's work there is good reason (especially in view of the remarkable results reported) for suspecting the presence of such a factor. The experimenter stood before the dog, being doubtless the center of the animal's interest, ready to give food or to strike as soon as the dog sprang up on to the chair. The punishment had to be administered quickly to prevent the animal from obtaining the food. One would expect that slight, nascent movements involved in giving food or striking would inevitably be made. Besides these and

[16] Moll, A. Hypnotism (4th ed.); tr. by Arthur F. Hopkirk. New York, Scribners, 1910.

[17] Pfungst, Oskar. Clever Hans. Tr. by Carl L. Rahn. New York, Henry Holt & Company, 1911.

[18] Shepherd, W. T. Discrimination of articulate sounds by cats. *American Journal of Psychology*, 1912.

other possible changes of posture (e.g., strain and relaxation of neck- or body-muscles), are possible involuntary changes in breathing, etc., any of which the animal could quickly learn to associate with food or with punishment.

Kalischer indeed attempted two control-tests of the existence of secondary criteria. First, he asserts that he made "some" of his dogs temporarily blind, by sewing their eyelids together. He reports that the accuracy of discrimination was not affected. Now, if this temporary blindness were complete, this result indeed would show that the secondary cues if there had been any, were not visual cues; but it would not show that there were no secondary cues of another kind. Changes of tension in the operator's body-muscles, of breathing, etc., can be detected by other than visual avenues. I lay what may seem undue stress on this possibility, because, as will appear later, there is reason to believe that such cues, involuntarily given, were factors in some tone-discrimination tests which I made on *blind* dogs.

Besides this form of control, Kalischer destroyed one cochlea in some other "well-trained dogs." No disturbance is reported. When the other cochlea was destroyed, all discrimination ceased. Dogs subjected to extirpation of both cochlea before any training was attempted did not learn to discriminate at all. Kalischer regards this as evidence that the *other* dogs had ignored extra-auditory stimuli. The possibility still remains, however, that in the tests given the normal animals, the experimenter expected them to react when the food-tone was sounded, and to inhibit reaction when other tones were sounded; and that he made "unconscious" movements corresponding to his expectation, to which the animals reacted. On the other hand, in testing dogs in which the cochlea had been destroyed, it is possible that the experimenter, believing them to be deaf, did not expect them to react, and hence did not make the movements which one would expect in the opposite situation. The most honest introspection will not enable him to decide whether "unconscious and involuntary" movements were made. If would have been much better if Kalischer had applied some form of control tests with the experimenter and others as well out of the room.

Kalischer, however, was satisfied that the dogs were discriminating between "exclusively auditory perceptions," and on that assumption proceeded to operate on the auditory center as

defined by Munk. The details of his report of the operative procedure are as meager as are those of his behavior tests.

The first operation was the extirpation of one temporal lobe from an animal whose cochlea on the same side had previously been destroyed. According to Munk the *nervi acustici* make a perfect chiasmus, and this operation should render the animal completely deaf. On the same assumption, if the cochlea on one side were completely destroyed and the auditory area on the same side only partially extirpated, deafness to some tones only—high or deep according as the anterior or posterior region were mutilated—should be produced. Kalischer reports, however, that his animals reacted to tones as before, no matter whether extirpation was partial or complete. There was a noticeable disturbance in responses to commands and more or less disturbance of orientation, but no details beyond these statements are given in Kalischer's report.

Before proceeding to extirpate the opposite temporal lobe from these animals, Kalischer allowed from four to five weeks for recovery, during which he continued his training. He observed no change in the animals' discrimination. "Nach der ersten Schläfenlappenextirpation hatte sich kein Unterscheid in den Verhalten der Tiere bei der Dressurversuchen gezeigt. Die Tonunterschiedsempfindlichkeit und der Reactionen der Tiere waren die gleichen geblieben, gleichgültig, auf welcher Seite die erste operation ausgeführt worden war."

The extirpation of the temporal lobes, Kalischer says, followed in general the plan of Munk, but sometimes a larger area was removed, both wider and deeper (three-quarters cm. deep) and sometimes opening the ventricle.

When the second temporal lobe was removed from some animals the visual area also was injured, Kalischer asserts, so that "a part of the peripheral visual field in both eyes was lost."[19] After this operation the dogs no longer reacted to spoken commands, nor did they show by pricking of the ears or movements of the head any sensitivity to loud noises. Later they apparently began to resume such movements at loud noises and very loud commands, but did not learn to discriminate among them. Before the operation the least whistle or call had been enough to

[19] A reliable method of making an accurate test of the dog's peripheral vision would be valuable and interesting. Kalischer does not describe his method.

bring them forth. Even the movements of the head and ears at noises finally disappeared after destruction of the posterior corpora quadrigemina with a needle. The animals' reactions to tones, however, were much less affected. Tests were resumed from three to four days after the operation. Kalischer says that some disturbances of tonal discrimination followed—i.e., the animals did not always react and inhibit correctly. (The percentage of error and the number of trials are not reported.) But he asserts that the animals "undoubtedly discriminated" between their respective food-tones and "Gegentöne," and ascribes the disturbance wholly to the shock of the operation. This may be correct, but evidence is lacking. If the dogs failed to react properly to the different tones the assumption that their failure was due to some other cause than inability to discriminate, is a mere guess.

Kalischer continues, "from the second week on the animals began to exhibit the old relations; they snapped in accustomed fashion at the food-tone and shrank back at the 'Gegentöne,' and even to the tones adjacent to the food-tone." Indeed, the reactions "appeared almost automatic," the animals "attended exclusively to the food" and less than before to surrounding objects, and their discrimination seemed improved rather than diminished. They reacted correctly when chords and discords were sounded if they contained the food-tone. It was possible to retrain even the "most mutilated" dogs to react to a new food-tone and to inhibit reaction to the former one. Further, animals not trained before removal of both temporal lobes could be taught to make the same discriminations, although they required a longer time than did the others, since they were not easily accustomed to being handled and to making definite movements.

Kalischer does not consider the possibility that the dogs had been rendered deaf by the operation, and were continuing their choice of reaction or inhibition of reaction to certain tones on the basis of rhythmic or habitual order of presentation of stimuli, or of secondary, extra-auditory stimuli, although one would naturally suspect that this were the case. He asserts that no other conclusion is left to us but that the dogs were deaf to noises and not to tone. He concludes accordingly that the perception of noise and that of tone are different functions;

and that different end-organs and different centers are involved for each. The center for noise he locates in the temporal lobe, the afferent pathway to which passes through the posterior corpora quadrigemina. The end-organ he leaves indeterminate. On the other hand, he considers that the cochlea contains the end-organs for tone; and that the center for tone is infra-cortical and even below the posterior corpora quadrigemina, since the only known auditory pathways to the cortex pass through them. On the behavior side Kalischer concludes that we must attribute to the dog an exceedingly fine sensitivity to absolute pitch.

That the defects in his behavior method set forth above render unwarranted all the conclusions which he draws from his data, seems to me clearly evident.

In the foregoing pages has been attempted a rather extensive criticism of Kalischer's work. This to some readers may seem overdone. But to me it seems necessary as well as just, because he has set the pattern for subsequent work by other investigators [20] whose methods have been of the same general type. His work has commanded praise from certain physiologists, as well as from students [21] in other fields to whom some of the difficulties involved in a reliable experimental test in audition are evidently unfamiliar. It seems proper here to suggest that Kalischer would hardly have adopted so crude a method and relied so uncritically on the results obtained from its use, had he first familiarized himself with the previous investigations in comparative psychology and animal behavior. That he is unacquainted with modern behavior methods is indicated by his claim to authorship of the food-stimulus method. He would hardly have advanced such a claim had he been familiar with the work done by Lloyd Morgan, Thorndike, Small, Franz, Yerkes and Watson, all of whom and many others had been using the food-stimulus method for years. The method certainly has great antiquity. After this point had been raised against him [22] he repeated the claim in subsequent writings.

[20] Swift, W. B. Demonstration eines Hundes dem beide Schlaefenlappen extirpiert worden sind. *Neurol. Centbl.*, xxix, pp. 686 ff.
Also Rothmann, l.c., above.

[21] e. g. Bentley, I. M. *Psychological Bulletin*, April 15, 1912.

[22] Franz, S. I. Dressurmethode f. Zentralnervensystemuntersuchungen. *Zentbl. f. Physiol.*, 1907, pp. 583 f. See also Kalischer's reply immediately following. . Also Watson, J. B. *Psychological Bulletin*, 1908.

In February, 1908, Rothmann [23] reported to the Physiologische Gesellschaft of Berlin some auditory tests which he had made before and after operations on several dogs, for the purpose of testing Kalischer's findings. It appears that about the time of Kalischer's communication, Rothmann was trying to ascertain the function of the posterior corpora quadrigemina. He was unwilling to accept Kalischer's conclusion that the center for pitch is infracortical and lies even below the posterior corpora quadrigemina. His reasons are: (1) That such an assumption does too much violence to definite localization theories already fairly established; (2) that the dog's discrimination and reactions are undoubtedly very complicated processes, and accordingly, to make them independent of the cerebrum would be practically to abandon all the useful doctrines of the relation of the cortex to "psychical" acts which prevail at present in physiology and pathology. Finally he suggests that in Kalischer's work secondary criteria were possibly not excluded.

He adhered to the following routine in conducting the daily tests on each animal: The stimulus tones were struck on the same organ used by Kalischer and Munk. The experimenter sat behind it "completely concealed by the high pipes, but so that he could observe the dog." "The meat was laid on a footstool before the dog, while the animal scampered freely hither and thither about the room. This had the great advantage that the tone could be struck while the dog was in another part of the room, with his head averted from the food." A *Diener* was posted behind the stool, to drive the dog away when he attempted to take the food except at the food-tone. Rothmann had suspected that Kalischer's dogs, which after the destruction of both corpora quadrigemina and the consequent cessation of all signs of attention to other noises yet continued to behave correctly at tones, may have been reacting to "unconscious helps," as had *Der kluge Hans*. He substituted the *Diener* for the experimenter at the feeding-place, apparently considering that the untrained *Diener*, who, however, must know the food-tones, was less likely to give the animal "unconscious helps" than would be the experimenter, who was "interested" in the

[23] Rothmann, Max. Ueber die Ergebnisse der Hörprufung an dressierten Hunden. *Arch.* 10 *f. Physiol.*, 1908, pp. 103 ff.

problem. As a matter of fact, perhaps unconsciously, Rothmann exposes the weakness of his assumption. He says: "If a wholly disinterested stranger, were introduced for the giving of the food, then it developed that the dogs undertook to get the food at *first even without a tone, or at wrong tones*, but only in the beginning. As soon as they had accustomed themselves to the change, they did their work correctly." (Italics mine.) Here it is evident that they were not disturbed by *fear* of the stranger. The simplest explanation is that, missing the first *Diener's* threatening signs, they reacted at random until they became used to those of the new attendant.

Rothmann does not report the following facts: (1) The number of animals used; (2) the number of daily trials; (3) the order of presentation of stimuli; (4) the duration of the respective stimuli; (5) the position of the animal with reference to the food when the respective stimuli were given; and (6) the experimenter's criterion of discrimination.

The importance of (1) and (2) is self-evident to the experimental behaviorist; that of (3) and (6) has already been pointed out in the comment on Kalischer's work; and Rothmann's admission of the disturbing effect of (4) on his own work has already been quoted. The importance of (5)—the position of the animal when the stimulus is given, is very great, as it may easily become a basis of reaction. As illustrative of this point, the reader is referred to page 53 of this work for a record of a control test made by the writer.

Besides training to tones, Rothmann trained some of his animals to come for food at the words "*Komm her*," and to refrain from coming at the words "*Kopf scher*," both combinations being sung on the same tone. Reaction to other words of command was also taught.

The following operative and post-operative procedure was followed: Extirpation of both posterior corpora quadrigemina was performed on four dogs. Three had been previously trained. After the operation, two of these three were trained for about a month to discriminate c-1024 d.v. from the other c's on Rothmann's organ, but without success. The fourth animal, previously trained to react only to c-1024 d.v., and which had learned the problem "faultlessly," was again subjected to the training process beginning four weeks after the operation. Three

weeks were spent in training to the same tone without success; following which twenty-three days were spent in the endeavor to teach the animal to react to the words "*Mach schön*," with the same outcome. From Rothmann's brief account one gathers that the animal reacted when noises or tones were made but did not discriminate among them. Post mortem showed total destruction of the posterior corpora quadrigemina in all the animals.

Extirpation of both temporal lobes in five dogs produced deafness to both tone and noise when the entire area described by Munk was removed; if the removal was not complete, some traces of the reactions remained. A sixth dog, however, not previously trained, having been deprived of both temporal lobes and of one convolution of the *gyrus sylviacus*, was "successfully trained" in three weeks to react only to c-256 d.v. Seven days sufficed to perfect reaction to the words "*Nimm Fleisch.*"

In two dogs not previously trained, both internal geniculate bodies were destroyed. Neither could be trained to respond to either tone or noise. From these results Rothmann concludes that the dog's auditory center lies in the temporal region, but that it extends over a wider area than that defined by Munk. According to him the pathway from the end-organ passes through the posterior corpora quadrigemina and the internal geniculate bodies.

The anatomical findings thus announced are certainly less revolutionary and less spectacular than are those of Kalischer, and conform fairly to the generally accepted view. It should be remembered, nevertheless, that Rothmann's experimental procedure is as unreliable as Kalischer's, if indeed not more so.

Kalischer published in 1909 a report[24] of continued work done on reactions of dogs to musical tones. His conclusions from his former work had left the end-organ for tone indeterminate, and he wished to test the theory of Helmholtz regarding the function of the cochlea and the vestibular apparatus. In this same report he gives account of its extension to olfactory and color-vision tests on the dog. Apropos of the last mentioned part of his work it might be remarked that Kalischer's

[24] Kalischer, Otto. Weitere Mitteilung ueber die Ergebnisse der Dressur als physiologischer Untersuchungsmethode auf den Gebieten des Gehör—,Geruchs- und Farbensinns. *Arch. f. Physiol.*, 1909.

apparatus is subject to several gross defects which had been eliminated in color-vision tests on animals made by Yerkes some years before Kalischer's work was published, by the use of the food-stimulus method.

The auditory tests reported in this article were carried on by the same method as was employed in the earlier work, except that some animals were trained to respond to as many as three (single) food-tones—high, middle and deep. Different animals responded to tones from F_2 to f^3, sounded on the harmonium. Kalischer says that in the beginning of this experiment when the food-tone was sounded he helped the animals perform their reactions; but that later they performed them voluntarily "without any help being given." Most of the animals had already been trained to react to one food-tone, and Kalischer tells us that the training had to be continued long enough for the new food-tone to become "fixed in memory" before reaction became sure. How long a time was required he does not say.

After the animals had been trained to two food-tones, one high and the other deep, one labyrinth was completely destroyed, making the animal wholly deaf on that side. The method used was the mastoid opening of Heidenhain. Destruction of both cochlea and vestibular apparatus was made complete. Training was continued for two or three weeks after the operation, which had not damaged the dogs' accuracy in discrimination. By the same method the second cochlea was then exposed, and the part of the cochlea desired was removed by first piercing the "knee-capsule" covering the cochlea with a fine drill-point, and removing the parts with a needle. One animal in particular, trained before the operation to respond only to food-tones A_1 and c^3, suffered no loss of accuracy in discriminating between these tones and all others. Post mortem showed entire destruction of one cochlea, and removal of the other as far down as the lowest turn. Only this small portion of the cochlea and the vestibular apparatus were left intact. The part of the organ of Corti and of the membrane of Reissner contained in this part of the cochlea, and also the cells of the spiral ganglion which belong to this turn of the cochlea, were uninjured. Reaction to the spoken words "*Sechs*" and "*Drei*" was also perfect, the animal being allowed to take food when they were spoken.

In another animal post mortem showed that only the lowest turn of the cochlea, with the part of the organ of Corti and of the ganglion cells contained in it, was destroyed. The parts lying in the middle turn of the cochlea, however, were atrophied, and the vestibular apparatus was slightly damaged. This animal, which had been trained to react only to B_1 and c_3 as food-tones, and to spoken words, and from which previous to this operation the other cochlea had been removed, had reacted both to tone and to noise as had normal animals.

From other animals, one cochlea having been removed, one side of the remaining cochlea was also extirpated, leaving the other side intact, and not injuring the vestibular apparatus. These after the operation did not react to their food-tones until helped. They had lost their "absolute" sensitivity to pitch, says Kalischer, but could still be made to discriminate between food-tones and "Gegentöne," even if the difference was only half a tone. In other animals in which the vestibular apparatus was more or less injured by this operation, disturbances corresponding to the degree of injury were observed. That is to say, they could not be made to differentiate between tones lying close together in pitch, but could differentiate between tones lying farther apart.

From these data Kalischer concludes that the theory of Helmholtz and others that the different parts of the cochlea and of the basilar membrane act selectively as receptors of long or short sound-waves, is untenable. Also, that the vestibular apparatus possesses an auditory function, and is necessary for pitch-discrimination. Further, that all clang-analysis takes place "in the peripheral end-organs of the nervus acusticus."

In an *Anhang* to this part of his report Kalischer says that some of his dogs were brought to discriminate between trichords as well as between simple tones; for instance, an animal trained to react to e^1 and to inhibit reaction to $e\flat^1$, would also react to the chord $c^1e^1g^1$ and inhibit reaction to the chords $c^1 e\flat^1 g^1$, $c\sharp^1 e\sharp^1 g\sharp^1$, $d^1 f\sharp a^1$, etc. He further says that by the use of a mouth harmonica he was able to demonstrate in experiments conducted in the stable, that the ass also possesses sensitivity to "absolute pitch." The total time required for this demonstration was about one and one-half weeks.

Swift [25] who was interested in the "psychical" processes involved in the reactions of Kalischer's and Rothmann's dogs, as well as in their localization theories, trained two female dogs "after the method of Kalischer," to discriminate between c^1 and e^2, sounded on trumpets. The c^1 was the food-tone. Fourteen days sufficed to perfect the reactions. The number of trials a day is not given. No control tests showing that the animals were not reacting to other than auditory stimuli are reported. A month of rest was allowed before operating.

On the first dog, extirpation of the left temporal lobe was performed. This, according to Swift, produced right hemianopia. He does not say how this fact was determined. The reactions to tone were undisturbed when the tests were resumed, three days after the operation. Ten days later the right temporal lobe was also extirpated. This, Swift says, rendered the animal's blindness nearly total, and also produced left hemiplegia. Discrimination between the tones was not disturbed. The same operations were performed on the second dog, but both lobes were removed at once. She, too, discriminated as unfailingly as before. This, Swift thinks, demonstrates that the center for pitch cannot lie in the temporal lobe. He does not agree with Kalischer, however, that the center for tone can be infra-cortical. He argues that the dogs' reactions involve a complex "intellectual process," and reveal a well developed "ability to think:" hence, that the cortex must be involved. He believes, therefore, that the center lies in the cortex, but outside the temporal region.

If Swift followed the method of Kalischer, as he asserts, then the animals could have reacted to many other cues than auditory, as has been shown in the remarks on Kalischer's first experiment. Nor is it safe to assume on the results of casual tests that a dog is or is not suffering from defective vision. Extensive observation of the reactions of blind dogs to controlled stimuli, some data of which are included in a later part of this work; and tests by standard methods on the vision of normal dogs, made by Haggerty and by myself, have yielded results quite at variance with the popular attribution of visual keenness to the dog. Further it should be said that Swift's

[25] Swift, W. B. Demonstration eines Hundes den beide Schlaefenlappen extirpiert worden sind. *Neurol Centbl.*, xxix, pp. 686 ff.

animals may have been reacting to pain and not to tone; an e-640 d.v. trumpet-tone, sounded at close quarters in a small room, is certainly both loud and high enough to occasion pain in the human subject. And finally, it is a commonplace that Swift's ascription to the dog of "intellectual" processes and a highly developed "ability to think," is unscientific. There is no possible means by which we may experience an approximation to the dog's "content," in the first place; and besides, we can interpret his behavior adequately and far more surely without relying upon a construct. Indeed, we can explain his reactions quite satisfactorily on the assumption that he has no mental content; and the assumption can no more be disproved than can the one of Swift's.

As appears in the foregoing discussion of work done by other investigators, the problem of localization of the auditory center has been left by them in an unsatisfactory state. Rothmann and Munk place the auditory center in the temporal region; Munk asserts that different portions of the region perform highly differentiated functions. Kalischer insists that the center for pitch is infracortical; that tone-discrimination is made in the "peripheral end-organs of the *nervus acusticus;*" and that the center for noise is another center than that for pitch. Swift tells us that the center must be cortical, but that he has demonstrated that it cannot lie in the region pointed out by Munk and Rothman. As has been pointed out, the methods of conducting behavior tests employed by all these experimenters are decidedly crude and their widely divergent conclusions may be explained at least partially by reference to the methods of controlling the animals' behavior.

PRELIMINARY EXPERIMENTATION

In April, 1910, at the suggestion of Professor Watson, I began as an experiment in comparative psychology a series of tests on the audition of dogs, in the hope of accomplishing the following purposes:

1. To see whether the behavior results of Kalischer and others could be confirmed by tests made under more reliable conditions of control.

2. To devise a satisfactory method of testing the limits of pitch-discrimination in the higher vertebrates.

3. To find the difference-threshold for pitch in the dog.

4. If preliminary results should justify the attempt, to repeat the tests on animals on which after training, extirpation operations had been performed by a competent surgeon, and attempt to interpret the disturbances which might result in the light of the post mortem examinations.

The statement may properly be made now that neither of the two goals last mentioned has as yet been reached.

The animals used were two females, litter sisters, mongrels, littered June 15, 1906. At about their second day of life a surgeon in the state hospital for the insane at Wards Island, New York, had assured the continuance of temporary blindness as long as might prove desirable, by first scarifying the edges of the lids and then uniting them with stitches. This caused the upper and lower lids to grow fast together before the ninth day, at which time the puppy's eyes ordinarily open. During the preliminary experiment described herein the dogs were still in the blind state. When this work was begun they had been in the laboratory for over a year but no experiments of consequence had been made with them. Both were laboratory pets and very affectionate, but rather nervous in strange situations.

It seemed best, in order to obtain decisive results, to present the animal with at least fifteen stimuli at each daily test. If a small number—say five, is chosen, variation in the order of presentation is too greatly limited; and if the animal is nervous at first the record is not a fair indication of his discriminatory work.

The animals used in this experiment were fed once a day—at the time set for the experiment, which was early in the afternoon. No food was given until the day's work was begun. If the animal appeared unduly eager to begin work one or two bits of meat were usually given before the stimulus was presented, in order to make the dog better contented. After each day's series each animal was allowed to eat as much as she desired at the time. The food was scrap meat, thoroughly cooked by boiling, and mixed with stale bread soaked in its liquor. Milk was also given from two to seven times a week. Both these and the other animals used in later work remained in splendid condition throughout the experimental work.

It seemed better also to adopt a different test of discrimination from that used by Kalischer, Rothmann and Swift. This, as has been mentioned, was to allow the animal to take food at one or more tones and to refrain from it at others. If an animal is hungry and eager to obtain food, one would expect a tendency to react to the mere striking of any tone; while if the animal is timid there may be a tendency to inhibit reaction, even though the tone were "recognized" as the food-tone. So, to the two tones used as stimuli, two reactions quite different were chosen; to the deeper tone the animal was trained to react by placing her forefeet on a chair at the operator's left, and waiting there for food; to the higher tone, by mounting a low box at the operator's right, and "sitting down" on it until fed. Between stimuli the animal sat on the floor, at the experimenter's feet. Food was given after a correct reaction had been chosen. In case of incorrect choice she was recalled without being fed unless she was unusually nervous, in which event occasionally she was allowed to perform the correct reaction and take food, the reaction being recorded as an error. The problem was considered "learned" when the animal had performed three successive daily series of reactions without error.

The two stimulus-tones chosen were middle c (256 d.v.) and the g above (384 d.v.). The tones were sounded at first on two standard tuning forks, mounted on wooden resonators, and struck by hand. The forks were placed close together on a shelf in front of the experimenter, and rested on heavy cotton felt pads. Their relative position was frequently changed. Later in this experiment the tones were sounded also on several Stern variators, large and small, blown from a Stern tank, and carefully tuned each day to the tuning forks. The merits and defects of this apparatus will be discussed later in this paper. Each tone was sounded until the animal had reacted—usually not more than one and one-half to two seconds.

For about six days, the animals, both of which were seemingly frightened when the forks were first struck in their presence, were "put through" the proper reactions—to one tone several times and then to the other for the rest of the series. As soon as they showed a tendency to react voluntarily they were allowed to work without consciously given help, at least, from the experimenter. Records were taken from this point on.

Four problems were given:

1. Discrimination between the two tones sounded on tuning forks struck by hand.

2. Discrimination between the two tones sounded on the blown variators.

3. Discrimination between the two tones sounded on forks and on large and small variators indifferently.

4. Discrimination between chords containing one and the other stimulus-tones, respectively.

The results are summarized in the following table:

Problem	Dog	Began	Finished	Days worked	Trials required for learning
1	1	4/19	5/ 7	19	285
	2	4/18	5/14	27	405
2	1	5/12	5/19	8	120
	2	5/19	5/24	6	90
3	1	6/ 1	6/11	12	150
	2	6/ 1	7/18	40	600
4	1	8/ 6	10/ 1	41	615
	2	8/ 4	9/30	44	660

The tables showing the daily percentage of error are found on pp. 24ff. The longer learning-time of Dog 2 in experiment 3 was due to disturbance by the falling of a piece of apparatus duing an experiment. She refused to work for nine days and then resumed responses of any kind only after a great deal of coaxing and petting.

Care was taken to sound the tones with varying degrees of intensity. The tones of the variators can be made faint or loud at will by increasing or lessening the diameter of the opening of the air-valve leading to each pipe. Such a change produces also a change of pitch. The latter must be corrected by retuning to the fork. Further the same stimulus-tones can be blown on any one of two or three variators. By this means tones of the same fundamental pitch, but of quite different timbre, were given. It was thought that this might prevent the animal from reacting to constant differences of intensity and timbre. The relative position of the different resonators was also frequently interchanged, to prevent possible localization from becoming a factor.

In experiment 4 the following chords were used: (1) Containing c′ (256 d.v.) c′-e; c′-e′c″; g-c′-e′; c′-eb′; c′-eb′-c″; g-c′-e♭′; a-c′; f-c′; f-c′-a′; a-c′f′; c′-a′-f′; (2) containing g′ (384 d.v.); g′-b; g′-b′-g″; g′-b♭′; g′-b♭′-g′; e′-g′-c″; e♭′-g′-c″; g′-b′-d′; d′-g′; d-g′-b′; g′-b′-d″. These chords were used indifferently, regard being paid only to which of the two stimulus-tones was contained in the chord. That the chord might be sounded at once, an extra valve was put on the main pipe leading from the tank, which was to be kept closed except when the stimulus was given. Thus the stops opening the valve leading to each variator could be pulled out as desired, and when the main valve was opened the entire chord would be sounded at once.

The results of this experiment approximate closely those obtained by Kalischer and Rothmann. I have never observed, however, what they both report, namely, that after a few trials have been given the animal becomes "fatigued." If the animal is left alone as many as thirty trials may be given in control tests, evoking a prompt response each time. This makes me suspect that the failure of Kalischer's dogs to react to the food-tones, if the latter in a four or five minute series were "allowed to sound often one after the other," was due to a lack of discrimination rather than to mere fatigue.

A control test of retention was given sixty days after the last problem had been "learned." Following a private discussion of Kalischer's contention that the dog has an "exceedingly fine sensitivity to absolute pitch," (of which, however, I have never been convinced) I invited the members of the psychological journal club to witness a test of the animals' ability to react properly to their old stimulus-tones. The animals had not worked on the problem since it had been discontinued—in fact, they were then engaged in learning to open a problem-box for their daily food. The two stimulus-forks used in the first problem were used and struck as before. Each dog was given eight stimuli, in the order indicated by one of the observers watching the experiment through a glass door. Each dog reacted without error. Dog 1 was sniffing at the place on the floor where her problem-box usually stood, and when the first fork was struck, merely crouched and kept sniffing hastily at the floor where she stood. When after perhaps two seconds the fork was struck again, she again crouched and in some confusion found

her way to the chair and mounted it properly. All her other reactions and all those of Dog 2 were prompt.

TABLE 1

Discrimination Between Forks c-256 d.v. and g-384 d.v. Struck by Hand

Day	Dog 1 % Accuracy	Dog 2 % Accuracy
1	47	40
2	53	33
3	60	47
4	40	73
5	40	40
6	47	47
7	53	53
8	60	53
9	80	47
10	66	47
11	86	67
12	73	47
13	86	80
14	80	67
15	93	87
16	93	80
17	100	87
18	100	87
19	100	93
20		93
21		80
22		87
23		100
24		87
25		100
26		100
27		100

TABLE 2

Discrimination Between Variators c-256 d.v. and g-384 d.v.

Day	Dog 1 % Accuracy	Dog 2 % Accuracy
1	80	80
2	73	80
3	80	93
4	86	100
5	86	100
6	100	100
7	100	
8	100	

TABLE 3

Discrimination Between c-256 d.v. and g-384 d.v. Struck on Forks and Variators Indiscriminately

Day	Dog 1 % Accuracy	Dog 2 % Accuracy
1	47	60
2	40	66
3	53	20
4	47	00
5	73	00
6	73	00
7	87	00
8	100	00
9	100	10
10	100	00
11		20
12		33
13		47
14		40
15		66
16		80
17		80
18		47
19		40
20		60
21		53
22		53
23		73
24		66
25		73
26		80
27		80
28		66
29		73
30		87
31		87
32		80
33		93
34		80
35		93
36		93
37		93
38		100
39		100
40		100

TABLE 4

Discrimination Between Chords Containing c-256 d.v. and g-384 d.v. Sounded on Variators

Day	Dog 1 % Accuracy	Dog 2 % Accuracy
1	67	73
2	47	60
3	67	47
4	67	60
5	73	80
6	73	60
7	60	87
8	73	87
9	47	80
10	73	87
11	80	87
12	73	80
13	87	80
14	80	87
15	80	53
16	87	80
17	53	67
18	47	73
19	73	80
20	80	73
21	87	87
22	87	73
23	100	60
24	67	73
25	80	73
26	87	80
27	87	87
28	80	87
29	80	87
30	87	80
31	73	53
32	87	60
33	87	80
34	80	80
35	93	80
36	93	80
37	93	93
38	100	47
39	100	73
40	100	93
41		87
42		100
43		100
44		100

Although these results taken at their face value seem to confirm those of Kalischer and Rothmann, yet they were not wholly satisfactory. The experimenter had been in the room, near the dogs, throughout the experiment. While he was not yet trained to observe and to guard against the giving of less noticeable secondary cues, yet on casting the results it was easy to recall many times when an animal had changed her reaction if the operator happened to turn his head, shift his body-weight from one foot to the other, or catch his breath. Also, that if the stimulus-tone was not damped as soon as the animal had selected her feeding-place, she would sometimes go hastily to the other. Further there was room for doubt whether the order of presentation had been sufficiently irregular, as in the records of the animal's work on the first two problems, there were shown only the number of right and wrong reactions respectively to each stimulus-tone, the order of presentation not being given. These facts being considered it seemed better not to rely on the results at hand until other tests could be made in which these possible disturbing factors were eliminated.

Accordingly in the summer of 1911 the same two animals were subjected to control tests, which, through the kindness of Professors Angell and Carr, were performed in the laboratory of the University of Chicago. The two stimulus-tones chosen were middle c-256 d.v. and e′-320 d.v. It was believed that the animals would quickly learn to discriminate between these and that other tones could then be introduced, to which yet different reactions could be made.

In these tests the stimulus-tones were struck on standard forks by an assistant[26] who sat in a room twelve feet away, separated from the animal-room by two partitions, one of which was a nine-inch brick wall. A wooden tube four by six inches in cross-section was used to convey the sound into the animal-room. Between stimuli the animal was confined in a cage just under the sound-pipe, and when the stimulus-tone was struck, was released by the experimenter's pulling a string from where he stood, in the room adjoining, by which act the door of the cage was noiselessly released. In the opposite corner of the

[26] This part of the experiment was conducted with the assistance of Mr. J. W. Shields, then a graduate student in the University of Chicago, to whom my thanks are due.

room were two food-boxes, each above a chair which the animal was to mount with her fore-feet. The two chairs were fastened with sides together, and with their fronts secured to the wall, so that the animal had to face west in mounting the chair to be associated with the tone of the c-fork; and east in mounting the one to be associated with the tone of the e-fork. When proper choice was made food was dropped on to the chair from a chute above, which was opened by the pulling of a string in the hand of the experimenter. In case of incorrect choice the animal was recalled without being fed. The reactions were observed by the experimenter from without the room, who watched the work through a hole in the wall three inches square.

In the beginning of this experiment the animals were first given each tone separately, and "put through" by the operator. After eight or ten stimuli had been given the animal showed a tendency to go to the box of her own accord. After each animal had performed fifty consecutive reactions to the c-fork correctly without being put through, she was trained to go to the other box at the striking of the e-fork and allowed a like number of reactions. Then both stimuli were given irregularly in a given series, and the animals' unaided reactions were recorded. Each early developed a "position habit," at first usually choosing the box where she was last fed or avoiding the one from which she has last been recalled without being fed. Then followed in each dog a preference for one box or the other, causing its selection from 70% to 90% of the chances. Then each dog acquired a rhythmical habit, going to one box, now to the other, regardless of the stimulus presented. To break this up the animal was worked against her preference—the order of presentation being so arranged that the animal's method would seldom secure food for her. Later both animals reacted irregularly, but as appears in table 5, with little regard to the stimulus given.

After 37 days—505 trials each, the experiment had to be interrupted. There was little evidence of discrimination in the dogs at the end of the test.

There were some indications, however, that they might be failing to react correctly, not because of inability to discriminate, but because of lack of "attention." If on leaving the cage the animal immediately began a wide detour to the right or

left in going to the food-box, the reaction was nearly always correct; but if she started by a middle path toward the boxes, which were near together, the reaction was incorrect as often, at least, as correct. It was usually possible for the experimenter to predict from the animal's breathing when she was about to become indifferent. This stage was observed sometimes in the beginning of a series, sometimes only about the middle, and sometimes near the end. It could hardly be interpreted therefore, as fatigue, especially since the animal would always make *some* choice very quickly. The "delayed reaction" factor

TABLE 5

Discrimination Between Struck Forks c-256 d.v. and e-320 d.v.
(Control experiment, Chicago)

Day	Dog 1 % Accuracy	Dog 2 % Accuracy
1	00	10
2	00	00
3	00	00
4	33	40
5	40	47
6	40	73
7	27	40
8	53	10
9	60	40
10	67	53
11	73	40
12	27	53
13	33	33
14	53	53
15	33	73
16	30	27
17	30	33
18	60	47
19	80	33
20	50	60
21	70	40
22	70	60
23	70	53
24	50	53
25	20	40
26	40	40
27	40	53
28	60	10
29	50	20
30	60	53
31	30	90
32	40	53
33	60	60
34	80	53
35	80	53
36	30	53
37	60	60

is evidently present here, and the experimenter was unwilling to accept these negative results as conclusive until the tests had been made under such conditions as would compel the animal to make her choice very soon after the stimulus is presented.

From these preliminary experiments it becomes evident that in order to reach reliable results in the field of pitch-discrimination new apparatus must be constructed and such conditions fulfilled as will enable the experimenter to exclude certain vitiating factors inherent in tests like my first ones, and of the Kalischer and Rothmann type. An enumeration of these defects, with apparatus proposed for their elimination, is set forth in the section next following.

THE CONDITIONS OF A DECISIVE EXPERIMENT ON PITCH-DISCRIMINATION IN ANIMALS

It is probably evident that neither in the results of my own preliminary experiments nor in the work of the other investigators which has been discussed, can we be at all sure that the dogs were reacting only to auditory stimuli. Some obvious secondary cues have to be eliminated from the experimental conditions if results of future experiments are to be reliable. It seems worth while to mention these disturbing factors, some of which others have previously pointed out in describing discrimination-experiments of other kinds.

1. "*Unconscious helps.*" By this term is meant any sort of body-movements, which the animal can learn to associate with a definite reaction. Those likely to be made by the experimenter under such conditions as Kalischer's and Swift's, or by the assistant in Rothmann's experiment—namely, such nascent movements of the arms and body as would accompany readiness to strike or to step back to allow the dog to obtain food, are particularly vicious, as appears in the "Clever Hans" report. They can be detected visually by many animals. But visually sensed aids by no means exhaust the list. Suppose the operator has been in the habit of recalling the dog when a wrong choice is made, or of scolding him if he fails to inhibit, and encouraging him by a word if he is timid in reacting, when the problem is like Kalischer's and Rothmann's; a very slight change in

breathing will be noticed even by a blind animal. There are other movements of like kind, which serve as auditory stimuli. Now, there is only one reliable means of preventing disturbance from these sources: *Not only the experimenter but all others should be outside the room in which the animal is working.* Rothmann's *Diener* or any bystander can disturb the dog as much as could the experimenter, and indeed is more likely to do so, as the experimenter if he is honest is apt to take greater pains to be on his guard. Meeting this condition does not preclude the experimenter's putting the animal through the proper reactions in the first two or three days' work, although it is doubtful if this is desirable; but as soon as the animal is left to discriminate, the experimenter should leave the experiment room. In control tests, even though he be in another room, it is highly expedient that *the experimenter should not watch the animal while making his choice*, but wait until the choice is made. This will prevent the animals being given any auditory "unconscious helps." In my later work I observed this precaution, with satisfactory results.

2. *The order of the presentation of stimuli.* This must be varied irregularly. In a given series of say 100 presentations, the animal should be given 50 of each. In actual training work, I have found, as have also Yerkes, Watson and others, that it is usually unsafe to give the same stimulus more than three times in succession, as a position preference is apt to become established. In control tests, after the animal has really learned to discriminate, the number of successive presentations of the same stimulus can be safely increased. The best method I have used in training work for determining the order of presentation is the use of a well shuffled pack of cards; allowing those of one color to represent one stimulus, and those of the other color the other stimulus. If more than three cards of the same color appear in succession the extra ones can be laid aside until needed to break into an overlong series of the other color, or until the bottom of the pack has been reached. This method assures the variation being irregular, and eliminates the possibility of the animal's successful reaction merely to the order of presentation. The probability of the coincidence of an order so determined with the animal's established preference, is extremely slight. As has been suggested above, the experimenter

making up an order of presentation at random may too easily fall into a rhythm of his own.

3. *Duration of the stimulus.* This should be made as nearly the same for both stimuli as possible. If the animal reacts quickly the stimulus tone may be sounded until choice has been made; if he reacts slowly, however, the chances are that he will disregard the stimulus if its duration is much more than one or two seconds. This may work injury if the animal habitually "sets himself" to react when the stimulus has ceased—as some animals will do. If two tones widely different in pitch are used, the tendency of the higher one to die away more quickly than the deeper, may be a disturbing element; if the animal reacts slowly, both tones should be damped at the end of the time allowed, regardless of the animal's behavior.

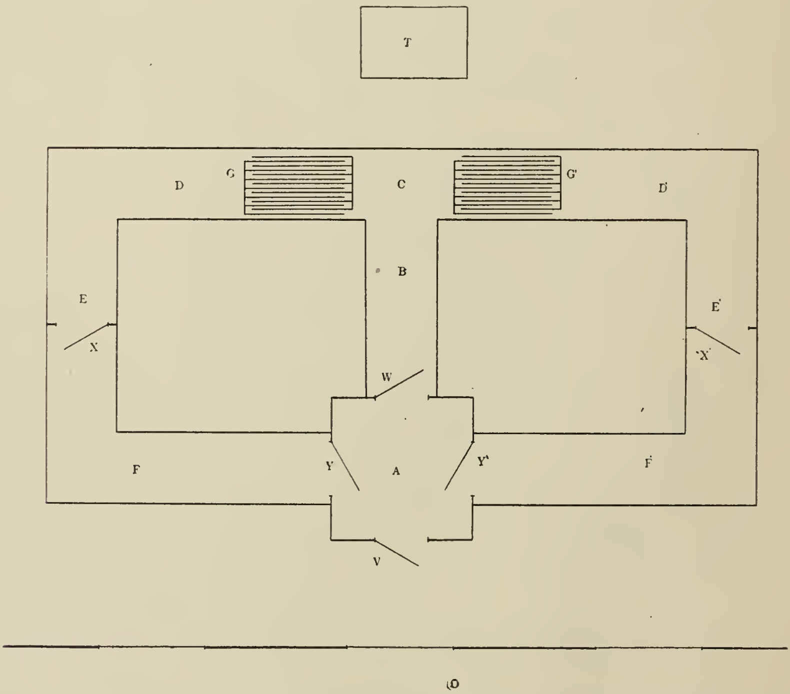


Figure 1—A, home-box; B, introductory alley; C, opening into alleys D and D′; E, E′, alleys entering food-compartments F and F′; G, G′, punishment grills; T, table containing stimulus-forks. V, W, X, X′, Y and Y′ are doors, automatically swinging in the direction indicated. The experimenter's place is in an adjacent room by window O in front of door V of the home-box.

4. *Position of the animal when the stimulus is given.* This should also be the same for all stimuli—or as nearly the same as is possible. I have already referred to a control-test of my own which illustrates the value of this precaution. This condition may be met by the use of the stimulus-cage which I have devised, a cut of which appears on page 32. The explanation of the sketch is as follows: A is the home-box, 4′ x 4′, in which the animal is placed between stimuli, entrance being made from without by the door V; B is an introductory alley, 6′ long and 2′ wide, leading to the alleys D and D′. These alleys are each 10′ long and open to alleys E and E′, which are shut off by the two doors X and X′. These doors, as appears in the cut, are made to open from the animal, and are closed automatically by a small coiled spring. Each is provided with an iron lift latch, which should be heavy enough to catch when the door is closed without attention from the operator. A string is fastened in a small hole drilled in the end of the lever of each of these latches, and run through an eye-screw in the door above, then through a pulley attached to the side of alley E or E′ as the case may be, then to the operator's place, so that by pulling the string the door may be unlatched and pulled open without the operator's leaving his place. When the string is released the door closes and latches itself. Alleys E and E′ open into two food-compartments F and F′. The covering of these boxes is provided with two doors, located near the end of alleys E and E′, through which food is dropped. Y and Y′ are two doors opening from food-compartments F and F′ into the home-box A. These doors are not provided with latches, as they close behind the animal, flush with the jambs, and cannot be opened by an animal which has not free use of its hands, such as has the monkey, raccoon, or the squirrel. They are provided with coiled springs, like those on doors X and X′. My animals would usually open these doors from the food-compartments, merely pushing their way into the home-box, but it is well to provide a means of opening them with strings as are doors X and X′, for the sake of timid animals. Door W is opened by means of a spring, as doors X, X′, Y and Y′ are closed. A heavy gut cord is fastened to an eye-screw near the top of door W, and run through a small hole near the top of the outside frame-work of home-box A, to the operator's station, where it is hooked until door W

is to be released. G and G′ are two punishment-grills—strips of brass about 3′ long, secured to a white pine board 3′ x 2′. Alternate strips are connected with the respective poles of the secondary coil of an inductorium, leaving the other end free. When the current is switched in, the animal's foot must rest on two or more of these strips, which are only 1 cm. wide and 1 cm. apart, thus completing the circuit and causing the animal to receive a shock. The inductorium should be placed outside the room in which the animal is being worked, and far enough away that the sparking noise will not disturb the experiment. The current may be shifted through G or G′ by a double-throw switch at the operator's station. My experience showed that in a cage of this size the grills G and G′ should be made longer than three feet; six feet would be much better. Some of the dogs used in these experiments would jump over the grill when they were shocked, instead of turning back. They probably would not have persisted in this attempt had the distance been greater. As it was, additional rods had to be run from side to side of alleys D and D′, above the grills, so that the dogs could not jump over them and escape punishment.

The frame-work of this cage is constructed of yellow pine, 1″ x 3″; the top and sides are covered with woven steel wire, having a mesh about 1 cm. square. Food is kept in both the food-compartments F and F′. The animal is given the problem of choosing a turn to the left into alley D, leading to food-compartment F, at one tone, and a turn to the right into alley D′, leading to food-box F′, at the other tone. The stimulus-tone may be struck while the animal is in the home-box A, and the animal released after it has been damped; or the tone may be sounded after the animal's release, say one-half second before he can reach the end of the introductory alley. If punishment is to be administered, the animal receives it instantly he makes the wrong turn.

In a part of the writer's experiments presently, to be described the experimenter sat at a table about four feet from door V of the home-box. When the animals should have begun to discriminate a screen could be interposed between the table and the cage to conceal the operator. Later the entire appa-

ratus was moved into another room, and the experimenter remained entirely outside the animal-room until after the animal had reacted and been admitted to the proper food-box. The animal was observed through the center window shown in Fig. 1.

Besides the elimination of the secondary criteria mentioned above, it is also desirable to eliminate another possible source of disturbance, namely the lapse of attention which may ensue if the animal's reaction is delayed. This may be accomplished by giving the stimulus very shortly—say within a second, before the animal's choice is to be made. The optimal time may vary with different animals, but it should be possible to control it. In using the stimulus-cage described above the stimulus may be presented at any time desired before the animal reaches the turn into alleys D and D′.

The criterion of discrimination should not be less than a perfect record, maintained through at least three days. The arbitrary standard of 95 perfect trials in the last 100, which some investigators of other kinds of discrimination have adopted, may be allowable; but certainly a poorer record will not suffice. The higher standard is preferable to this.

The final condition which must be fulfilled is the controllability of the stimulus. It is well known that musical tones differ not only in pitch, but also in intensity, timbre, non-musical concomitant noise, and perhaps in localization. These other characteristics must be controlled if we are to make the assumption legitimately that the subject is discriminating on the basis of pitch alone. In addition to this desideratum, it is also desirable that the conditions under which one experimenter works may be reproducible by another, that results may be comparable.

At the present time no satisfactory means is known of measuring the intensity of sound. It may be varied quite widely, however, in electrically actuated tuning forks and in blown pipes and bottle whistles; the latter vary in pitch with the quantity of air admitted. The method of varying the intensity of the stimulus in forks will be described later in this section.

The best means of controlling timbre is by the use of instruments which will give tones as nearly pure as possible. Reed instruments cannot be controlled in this respect. Tuning forks weakly actuated give tones as nearly pure as can be had, although even in these a high anharmonic partial can usually

be detected. Weakly blown pipes or bottle whistles are perhaps the next best. If nearly pure tones cannot be obtained, the next best plan is to have the tone of the same fundamental pitch sounded now on one pipe or bottle-whistle, now on another which is larger or smaller than the first. Thus tones of the same pitch but of quite different timbre can be produced. If the animal, after being trained to a tone on one instrument, shows disturbance when another instrument giving the same tone is substituted, it is safe to say that he was not reacting merely to the pitch of the tones, and that other characteristics were more or less prominent.

The same may be said of non-musical concomitant noise. A struck fork gives a peculiar "cluck," which is rarely the same in any two; a bowed string may have a peculiar scrape which lends individuality to it; a blown pipe or whistle always gives a whisper, which may be a part of its individuality; while the rattle of no two reeds is perhaps exactly the same.

A tone comparatively pure cannot be localized correctly in a closed room because of standing waves; its apparent localization shifts with the observer's position. Angell[27] asserts that it cannot be localized even in the open air. If pure tones cannot be made, the position of the stimulus instruments should be frequently changed in control tests. High overtones and non-musical concomitant noises may be localized quite easily by an animal, and serve as the basis of discrimination.

Of instruments which will fulfill these conditions, one's choice is limited to tuning forks and blown pipes or bottle-whistles, preference being by far on the side of the first. A reed instrument, such as the harmonium or the mouth-harmonica, which Kalischer used, does not admit of control of timbre, nor of satisfactory control of intensity, and the accessory noise is considerable. Trumpets, which were used by Swift, are not certain in pitch, and the timbre varies greatly with the pitch and intensity of the tone sounded.

If blown pipes or whistles are used they should be easily tunable, as the daily change in temperature and density of the air affects their pitch considerably. Differential organ pipes are fairly satisfactory. The Stern variators also meet this

[27] ANGELL, J. R. Localization of tone. University of Chicago decennial publications, Chicago, 1900.

requirement. The vernier scales and the card-board index glued on the dials of the variators, however, are useless and should not be relied on. There is wide difference between the marks on the scale and the actual pitches under variable atmospheric conditions; and the play of the cogs in the device for raising and lowering the piston, is in some cases greater than three points on the scale.

If pipes or whistles are blown from an ordinary Stern or Whipple tank they are not accurate in pitch within a limit of about 3% in either direction, as the air pressure is not constant. For preliminary or rough work they are often useful when blown in this way, but should not be depended on for finer work. The Stern tank is much too small. It will not blow a large whistle or a c-256 d.v. pipe. The air is so quickly exhausted that if it is in the same room with the animal, the noise of raising it is often disturbing. If chords are blown on variators blown from it, it requires filling after nearly every stimulus. For finer work Watson [28] has devised and installed in the psychological laboratory at the Johns Hopkins University an air-system consisting of a tank filled by a motor-driven positive pressure blower. The tank supplies air-streams from a distant room. The pressure is remarkably constant, and makes possible an accuracy of pitch in blown pipes or whistles far beyond that hitherto attainable. The apparatus is rather expensive.

The apparatus adopted for finer discrimination work of this kind is a system of "tandem-driven" tuning forks similar to that recommended and used by Helmholtz [29]. In the present tests the apparatus was arranged as follows: A c-64 d.v. fork is mounted in a room 100 feet distant from the experimental room for electric actuation. A diagram of this fork and its equipment is shown in Fig. 2. The electrical connection is as follows: From the positive pole of a six volt two ampere storage cell to a rheostat, thence to the pole a, through the fork and platinum contact p with the mercury cup c, to the magnet m, to the pole b, to the negative pole of the storage cell. Thus with each vibration of the fork the current is made and broken at the contact p with the mercury cup c. The mercury in c

[28] Watson, John B. Article as yet unpublished.
[29] Helmholtz, H. v. Sensations of Tone (Ellis' translation).

is kept covered with alcohol, and a secondary circuit through a condenser is made by connecting at pole a and the mercury cup c. This is to eliminate the noise of sparking.

In the experiment-room, on a table, T, about six feet from the end of alley B of the stimulus-cage shown in Fig 1, are placed the stimulus-forks. A diagram of one is shown with its mounting in Fig. 3. The ones mounted for this work are c-256 d.v., e-320 d. v., g-384 d.v. and c-512 d.v. As will be seen these vibration-rates are all simple multiples of that of the primary fork. The stimulus-forks are not provided with contacts but are mounted with magnets between the prongs. The current through these magnets is made and broken at each complete vibration of the primary fork, and the impulse thus given is sufficient to actuate the stimulus forks. The wiring is as fol-

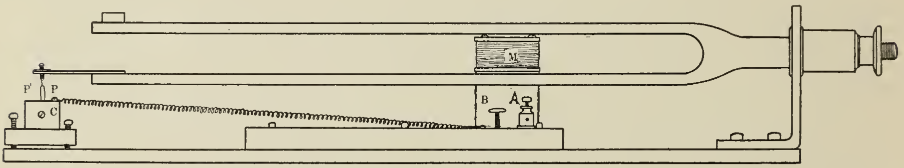
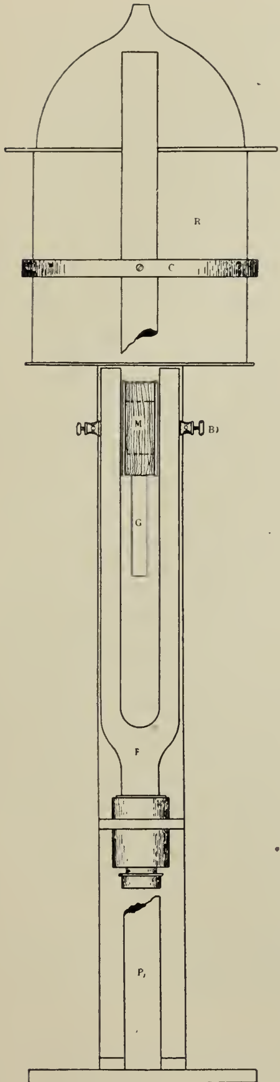


FIGURE 2—A, B, binding posts; C, insulated mercury cup; P, P′, platinum contacts; M, magnet.

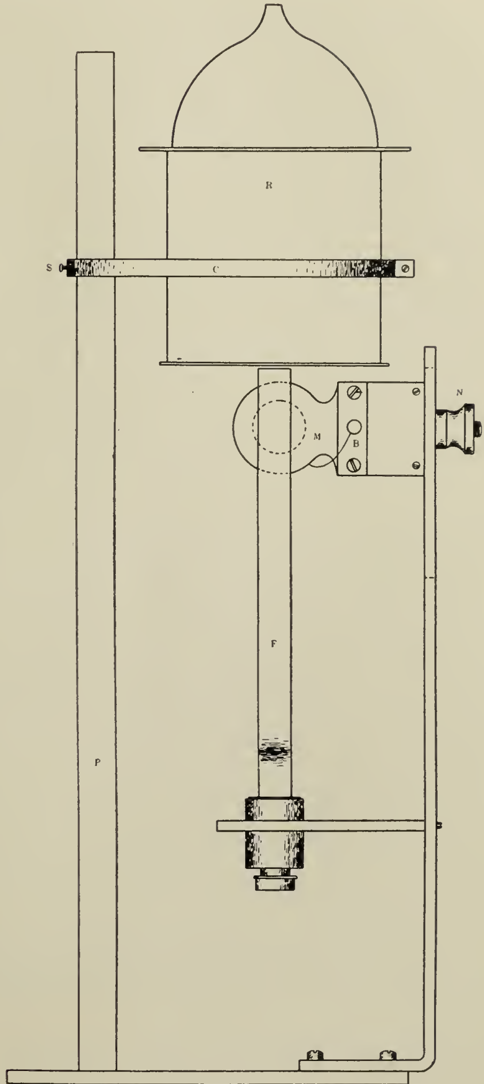
lows: From the positive pole of a four volt six amperes storage cell to contact a on the mounting of the primary fork, through the fork and platinum contact p′ to a second mercury cup not shown in the cut of the primary fork, but which is separated and insulated from mercury cup c by hard rubber mounting; thence to a rheostat, through the magnet coil between the prongs of the stimulus-fork, to a double-throw switch at the table at the experimenter's station; thence to the negative pole of the storage cell. The primary fork is kept going throughout the daily series; and the experimenter has only to turn the double-throw switch to cause either of the two stimulus-tones to sound.

Above the stimulus-fork shown in Fig. 3 will be noticed a König resonator. This mediates only the pure tone of the stimulus-fork. It is kept in place by a sleeve which is fastened to the upright rod on the fork's stand. A tone of maximum intensity is obtained when the resonator opening is about 1 mm from the ends of the prongs of the fork. The intensity can be



Front

Figure 3A



Side

Figure 3B

F, standard fork; R, König resonator; C, clamp; S, set screw; P, pillar supporting R; A, B, screw contacts; M, magnet, supported by nut, N, sliding through groove G in back wall.

varied widely by varying the distance between the resonator and fork. A vernier scale may be placed on the sleeve and the

rod, which shows this distance accurately. Then if the amount of current passing through the magnet of the stimulus-fork be known and the distance of the resonator from the fork be also known, it will be possible to duplicate these conditions and convert these readings into absolute units of intensity in case a means of measuring it satisfactorily should ever be perfected.

If a wooden resonance case is used instead of the König or Helmholtz resonator, results are not so satisfactory. Intensity can indeed be varied by varying the amount of current passing through the magnet of the stimulus-fork, but if the current used be strong, overtones become quite prominent. Besides the fundamental tone of the fork, there are also present a high anharmonic partial and an undertone of the pitch of the primary fork. The latter is caused by periodic increases in amplitude of vibration of the secondary fork, which synchronize with the vibration of the primary fork, due to the impulse of the current made and broken by the primary. This undertone, however, seems to be mediated by the wood of the table and of the resonance case. If the latter be removed and a König resonator substituted for it, and if the stand on which the stimulus-fork is mounted be padded heavily with cotton batting, then this undertone is not detectible by the human subject, even with the aid of a resonator. Under the same conditions the high partial cannot be heard by the best human observers at a distance exceeding two feet, so it probably does not work much disturbance. No overtones can be detected by use of the ordinary resonators. The maximum intensity of the fundamental is very great.

By this means may be obtained a tone which is practically pure, of widely variable if not measurable intensity, incapable of being localized by the human subject at least, and free from accessory noise.

Through the use of such a system and the stimulus-cage described above, I believe that it is possible to meet all the conditions of reliable tests on pitch-discrimination in animals which I have enumerated above: the elimination of unconscious helps; the elimination of the "delayed reaction" factor; the use of a decisive criterion of discrimination; and the controlability cf the stimulus.

FURTHER EXPERIMENTS ON TONAL DISCRIMINATION WITH IMPROVED APPARATUS

In the fall of 1911, the experiments on pitch-discrimination were continued in the Johns Hopkins laboratory, with the improvement in method just suggested. The two tones to be discriminated remained c-256 d.v. and e-320 d.v. They were sounded on "tandem-driven" forks mounted with König resonators, as described above. The reaction to the c-fork was a turn to the left at the end of alley B, and the choice of food-compartment F; that to the e-fork, a turn to the right and choice of food-compartment F′. The experiments had to be conducted at night—from 10 to 2 o'clock, when a quiet building could be had. In addition to Dogs 1 and 2, two normal female puppies, littered June 1, 1911, of which Dog 2 was the dam, were introduced as a control. These animals are referred to hereafter as Dogs 3 and 4.

The first two or three days of work was spent in feeding the animals in the stimulus-cage, and getting them accustomed to passing through the doors without hesitation. After they had become apparently "at home" in the new environment, each animal was "put through" the proper reactions to the two tones for three series of fifteen trials each, and then left to work out the problem for herself. Punishment was not introduced until the twenty-first day of training. The results were not satisfactory. The animal's reactions were greatly retarded in every case, and a certain disturbance resulted which none of the animals entirely overcame. A shock too weak to be disagreeable or even to be perceived when applied to the human subject's dry hand, would often cause great disturbance in an animal which had ignored it for several series. Care was always taken, too, to weaken the current still more if the dogs' feet were wet.[30]

For several weeks Dog 1 would go to grill G′, mount with the left foot the sill on her right, and reaching under the left fore-leg with her right forepaw, would scratch the grill vigorously for as long as five minutes, sometimes, barking furiously all the while. The stimulus-tone was being sounded continuously—or at intervals of one second from the time she was

[30] Breed, in his work on vision in the chick minimized changes in shock conditions by having the floor of the home-box covered with moistened material so that the animals' feet were *always* wet. This precaution seems well taken.

released from the home-box. After prolonging this behavior, she would suddenly proceed or turn back and choose the opposite alley. Strange to say, some of her best "accuracy" records were made during behavior of this kind. Dogs 3 and 4 insisted on leaping over both grills from the beginning—even before punishment was introduced. Later, rods were thrust through the meshes of the wire forming the sides of the alley, which compelled these dogs to creep under them and walk across the grills. Both these animals usually consumed some minutes in hesitation before choosing, after punishment was introduced, and

TABLE 6

Discrimination Between c-256 d.v. and e-320 d.v. Sounded on Tandem-driven Forks in Standard Cage

Day	Dog 1 % Accuracy	Dog 2 % Accuracy	Dog 3 % Accuracy	Dog 4 % Accuracy
1	20	67	20	60
2	30	70	00	40
3	30	50	70	70
4	20	30	70	50
5	10	70	30	50
6	30	40	60	40
7	20	70	50	40
8	20	70	30	60
9	70	40	20	50
10	30	50	20	20
11	60	47	60	53
12	40	70	30	30
13	40	60	60	40
14	20	30	30	40
15	40	60	30	50
16	40	60	40	60
17	70	90	30	70
18	80	50	30	60
19	60	60	50	10
20	47	53	30	30
21	53	66	33	73
22	53	60	53	53
23	67	67	40	47
24	60	67	40	47
25	40	73	50	70
26	20	53	50	73
27	33	33	50	60
28	60	40	40	10
29	40	33	47	67
30	33	60	20	53
31	60	67	60	46
32	73	60	53	47
33	80	33	40	53
34	47	40	80	40
35	80	66	33	47
36	50	46	53	80

TABLE 6—Continued

Day	Dog 1 % Accuracy	Dog 2 % Accuracy	Dog 3 % Accuracy	Dog 4 % Accuracy
37	66	46	73	53
38	40	40	40	40
39	60	53	53	67
40	53	53	60	46
41	53	60	53	47
42	53	53	40	60
43	73	60	80	40
44	67	73	60	60
45	67	60	60	47
46	53	60	80	60
47	40	73	53	47
48	73	67	47	47
49	73	53	67	53
50	73	47	53	53
51	60	67	40	53
52	47	53	73	47
53	47	53	40	73
54	33	40	40	66
55	47	33	33	60
56	53	26	53	23
57	47	47	47	33
58	33	20	47	80
59	33	53	53	80
60	47	47	67	60
61	67	33	47	40
62	60	33	73	40
63	80	40	73	73
64	60	46	80	73
65	53	20	60	67
66	47	53	53	67
67	60	53	80	53
68	80	60	60	60
69	80	47	60	40
70	67	53	80	60
71	40	47	47	40
72	40	73	53	53
73	40	60	60	67
74	67	47	40	73
75	60	40	80	73
76	60	47	53	40
77	60	53	40	60
78	67	60	40	67
79	47	40	60	47
80	60	40	53	47
81	53	73	67	53
82	47	60	73	47
83	80	53	60	47
84	47	40	53	47
85	80	53	73	73
86	60	53	40	53
87	60	60	40	47
88	67	47	47	73
89	80	60	53	60
90	47	60	80	40
91	67	53	73	40
92	60	53	53	10

Dog 3 developed a variety of position habits. After perhaps three weeks both became accustomed to conditions so that they did not hesitate in choosing the alley to a food-box; but neither could be made to turn back immediately a shock was received. Both would proceed to door X or X′ as the case might be, or cross the grill at least, before turning and going to the proper place. Dog 2 was little affected by punishment.

The learning records, showing percentage of daily accuracy, for ninety-two days of this work are shown in table 6. Not only was the problem not learned in that time, but no animal showed promise of improvement.

In the belief that the two tones may have been so nearly alike that the dogs could not discriminate, the experiment was abandoned for the time, and the animals were given the problem of associating release from the home-box at the stimulus-tone c-256 d.v. with food in food-compartment F, and release from the home-box without a stimulus-tone with food in food-compartment F′. Ten days (150 trials) was allotted for this work. There was no change in the dogs' behavior after the problem had been changed, beyond a return for one or two days to old position-habits which had been abandoned. At the end of ten days, as appears in the learning table below, discrimination was not established, nor was any improvement shown by any animal. This was taken as indication that the animals had been disregarding the stimulus-tones entirely. The results of this experiment are shown in table 7.

TABLE 7

DISCRIMINATION BETWEEN c-256 AND *No tone*

Day	Dog 1 % Accuracy	Dog 2 % Accuracy	Dog 3 % Accuracy	Dog 4 % Accuracy
1	40	40	60	53
2	53	47	60	53
3	67	60	47	47
4	53	53	60	47
5	60	53	47	60
6	47	47	40	50
7	67	53	20	00
8	40	40	60	60
9	47	40	47	60
10	40	67	53	67

The explanation of these unexpected results is not easy. It is of course possible that in ordinary noises the dog is stimulated

only by the high overtones, which in tones as nearly pure as those sounded on this apparatus, may have been lacking or so faint as not to be effective. There is of course, no proof of this but the point may be found worthy of future tests. These are not practicable at the present time,

It has been suggested by a critic that the stimulus chosen—a pure tone—is one so different from those stimuli to which the animal is provided with some form of instinctive response, that the animal should not be expected to learn readily to respond to it. Inasmuch as a pure tone cannot be localized, there may be some force to this suggestion. It seems to the casual observer at least that most of the auditory stimuli which affect the dog are significant because they are noises which can be localized and quickly associated with the things making them. However, admitting this point, the fact remains that it is useless to try to test any theory of localization of the center for pitch by experimenting on the dog, unless the animal can be made to discriminate on the basis of pitch-difference alone. This fact can be established only by the use of pure tones as stimuli, and by working under some such conditions as are proposed above as a standard. It is also open to question whether discrimination could not yet be established if by proper means the animal could be made to receive the stimuli.

The suggestion was also made that in the stimulus-cage the animal is in a "highly artificial" situation, and reacts under emotional constraint. This point is made much of by Shepherd, also, in his discussion of experiments in vision [31].

The truth of the first half of this suggestion is of course patent. Any experiment made under conditions of sensory control is necessarily "artificial." The animal which turns at the flutter of a bird in the leaves is probably affected by visual, olfactory and possibly still other stimuli than auditory. These stimuli taken together with the sound form the "situation" in which the animal is, and are readily associated with the response, which is more or less instinctive. The additional auditory stimulus may be only a "contributing agent," which makes the action of the others effective. The animal may be compared to the subject in a reaction-time experiment, prepared to react

[31] Shepherd, W. T. Mental processes of the Rhesus monkey. *Psychological Monographs*, 1911.

when the click or flash comes; and if we may speak for the moment in terms of consciousness, the degree of "attention" to the auditory stimulus itself is minimal. In the stimulus-cage, however, since the choice of reaction must be made on the basis of a single characteristic of the tone, the demands on his "attention"—at least until he has formed many new associations—are necessarily much greater than in the "natural" situation. Accordingly for a time at least his behavior should be expected to be quite different from what it would be in the "natural" situation. But there is no need for lamentation over this condition; it is imposed on every experimentor in sensation or sensory responses in which results are to be trustworthy.

As to the other half of this suggestion—that the animal reacts under emotional constraint—I do not feel so generous. Certainly some emotional disturbance attends the giving of punishment and I am by no means convinced that in working with an animal as highly organized as is the dog, it is desirable to use punishment. But once the animal has become accustomed to his daily work the signs of "emotional constraint" are few. The dogs which I have used are always eager to work; the excitement which attends the experience probably compensates in large measure for hunting and other instinctive reactions, which the animal in captivity cannot make. My dogs on being admitted to the experimental room certainly perform the reactions which a hunting dog makes when presented with a gun, and which are commonly interpreted as "signs of pleasure." [32]

EXPERIMENTS ON DISCRIMINATION BETWEEN NOISES

The point admitted in the discussion of the first part of the last mentioned criticism, may seem to some to strengthen a criticism which has been made: namely, that there is a hiatus

[32] I feel that it is hardly necessary to consider the suggestion which has been made, that the dogs which I used, being mongrels, should be expected to prove less sensitive to pitch-difference than blooded dogs; and further that acuity of audition varies greatly in different breeds. This certainly is Kalischer's report, but as has been shown in the remarks on his method, this result is no more reliable than the rest which he reports, as it is not evident that his animals were reacting to tone. I know of no other data offered as experimental evidence. But admitting the fact, the criticism is without point as applied to this work. My dogs used in the preliminary experiments showed the same apparent discrimination as did Kalischer's, Rothmann's and Swift's; perhaps greater, because they actually made *perfect* records for three days in succession. The control tests indicate that this discrimination was only apparent.

in my results; that the discrimination shown by the animals in the preliminary experiment might not have been lost had the experimenter gradually effaced himself. In other words: It may be too much to expect of an animal that he form the association between a sound and food in a certain box without some helps in the beginning at least; although he may be able to form the association with help and yet retain it after the helps have been eliminated.

It is manifest that the justice of this criticism cannot be settled *a priori*. Accordingly it seemed well to determine whether, and if so, how readily an animal thrown on his own resources can to discriminate between auditory stimuli alone. As pure tones were clearly out of the question for the time being at least, it was decided to use non-musical noises, which might present to the dog differences in other characteristics than that of pitch.

These experiments were conducted with the same animals and in the same stimulus-cage used in experiments 6 and 7. It had been removed meanwhile to a building at Homewood, which was more quiet than the one in the business section of the city could be. The experimenter was never in the room with the animals when the stimulus was given, but gave it from the room adjoining, where he could not be seen. After the animal had become started on the problem the experimenter did not even watch her while in the act of making her choice, but waited until after he had heard her cross the punishment grill. Thus the question of "unconscious helps" is eliminated. The order of presenting the stimulus was predetermined by the use of a well shuffled pack of cards.

The stimulus-noises were sounded on two ordinary electric buzzers. In the first experiment, designated as problem 8, one buzzer was placed over each of the two doors X and X′, but were merely hung over the edge of the cage by their flexible wire, without touching the cage itself. This was to lessen the probability of the animals reacting to vibration of the cage. The buzzers were actuated by current from two ordinary dry cells connected in series; the current being made by the operator pressing a simple contact key. Being placed over the entrance-doors to the food-compartments, they could be easily and in-

fallibly localized by the human subject. There was a noticeable difference in intensity, that of buzzer 1, placed in this experiment over door X, being considerably the louder. The quasi-tones were also of different pitch, that of buzzer 2, over door X′, being near the third of buzzer 1. This selection was made deliberately. The timbre of the two respective sounds also differed. The sound of buzzer 1 was decidedly nasal, while that of buzzer 2 was quite brilliant. Since these conditions unfortunately are not reproducible elsewhere this description should suffice. In a word, the two stimuli differed in frequency, amplitude, form and direction of the sound waves.

Contrary to the method employed at the beginning of the experiments on tone-discrimination, the animals in this experiment were not "put through" at the beginning, but left to form the associations between a particular sound and a particular food-box for themselves. Punishment was not given in case of incorrect choice. Care was taken to make the duration of each stimulus one-half second, or as near one-half second as possible.

The problem assigned the dogs was the association of the sound of a given buzzer with choice of the food-compartment over which the buzzer was placed. For the first two days after the animals were introduced to the problem each dog tended to react negatively to the stimulus. This was followed, except in case of Dog 4, by a tendency to choose food-compartment F′ regardless of the stimulus presented. This was broken up on the third day of the experiment by sounding buzzer 1 a second time after the animal had wrongly gone into alley D′. After only two or three repetitions this produced a returning into alley D. It was not continued after this day, however, as the experimenter feared that the animal might make it, rather than the actual sound of the respective buzzers, the cue for reaction. The learning tables, which follow, reveal a situation quite different from that of the tone-discrimination problem.

This experiment shows plainly that the dog can learn very quickly and without help to discriminate between two auditory stimuli. The question remains whether the discrimination in this case was on the basis of pitch, intensity, timbre or localization. During the experiment the animals often pricked their ears and turned their heads toward the sounding buzzer, so it

TABLE 8

DISCRIMINATION BETWEEN BUZZERS

Day	Dog 1 % Accuracy	Dog 2 % Accuracy	Dog 3 % Accuracy	Dog 4 % Accuracy
1	67	47	53	47
2	60	60	47	60
3	73	87	47	80
4	87	80	73	93
5	73	100	67	93
6	87	93	80	93
7	93	100	87	100
8	87	100	100	100
9	60†	100	100	100
10	100	67*	100	
11	100	100		
12	100	100		

seemed evident that they were localizing the sound, at any rate. It seemed well, therefore, to ascertain what effect interchange of the buzzers would have on the dogs' reactions. In this control-experiment, designated as problem 9, buzzer 1 was placed over door X′ and buzzer 2 over door X. The sound of buzzer 1 was to be associated with food in compartment F, and that of buzzer 2, with food in compartment F′, as in problem 8, just learned. The difference in conditions was that food was now to be obtained in the compartment *opposite*, instead of at the sounding buzzer.

Each dog was continued for five days on problem 8, which had been learned some three weeks earlier. The animals had done no work meanwhile, but the feeding hour had remained the same. Each animal had given at least three successive days of perfect records immediately preceding the beginning of problem 9. The first day's record of each animal on problem 9 immediately follows. The letters R and L signify right and left compartments, respectively.

This control test shows quite clearly that the location of the source of sound with respect to food is the characteristic of the stimulus which had been determining the animal's reactions. Each dog had been simply going to the compartment

* The problem was "learned" on the ninth day. The record of the tenth day is of a control-experiment, described on page 53, made to show the disturbing effect of variable position of the animal when the stimulus is given.

† The animal's work on this day was disturbed by the falling of a heavy door near food-compartment F while the series was in progress. For the remainder of the day she refused to choose F under any conditions. She was left to run freely in the cage all night in order to overcome the disturbance.

Proper choice	Actual choice by Dog 1	Dog 2	Dog 3	Dog 4
1 R	L	L	L	L
2 L	R	R	R	R
3 R	L	L	L	L
4 L	R	R	R	R
5 L	R	R	R	R
6 R	*	L	L	L
7 R	*	L	L	L
8 L	*	*	R	R
9 R	L	*	*	L
10 R	L	*	*	L
11 L	R	R	*	R
12 R	*	L	*	L
13 L	†	L	*	R
14 R		L	*	L
15 R		L	*	L

over which a buzzer had sounded. Dogs 1 and 3 gave up after making a few reactions of this kind; Dog 2, having given up the problem and acquired a new interest, relapsed into an ancient position-habit; while Dog 4, a very active half-grown puppy, maintained the old basis of choice throughout the series without reward. The following table shows the learning-record of Dogs 1, 2 and 4. Work with Dog 3 was discontinued after the fourth day, as at that time she attempted to escape through the door in the top of food compartment F′, near door X′, and became entangled with the gut cord by which door X′ is opened. In her struggles she succeeded in wrecking some apparatus and was so disturbed by the experience that for three successive days she refused to leave the home-box.

TABLE 9

Discrimination Between Buzzers, Their Positions Having Been Interchanged After Discrimination had Become Established

Day	Dog 1 % Accuracy	Dog 2 % Accuracy	Dog 4 % Accuracy
1	00	07	00
2	27	33	20
3	20	53	53
4	60	60	67
5	80	53	87
6	73	73	100
7	80	87	100
8	93	93	100
9	93	100	
10	100	100	
11	100	100	
12	100		

* Refused to work.
† Removed.

These results show nothing new except for the record of the first day. There may be some significance in a comparison of the records of Dogs 1 and 2 with that of Dog 4. Both the older dogs required a longer time to overcome the habit formed in problem 8 although the time for learning problem 8 was as short for Dog 2 as for the younger animal.

At this point the experiments had to be abandoned. I think it well, however, to outline the program which it was my intention to carry out had conditions permitted, as I believe it a safe approach to an investigation of pitch-discrimination. First, it was proposed to have the animals form the simple association required under the conditions of problem 8. Then, as a new problem, let the two buzzers be brought nearer and nearer together, until they shall be together on the table near the end of the introductory alley B. If the animals can still discriminate, the characteristic of localization is eliminated. Then let a stimulus fork be substituted for one buzzer, and if discrimination can be established and maintained between the two sounds, substitute the second stimulus-fork for the other buzzer. If the animals learn to discriminate between the two tones, variations of intensity and other controls can follow. Discrimination between noises lies well within the dog's capacity. It may yet be possible to obtain reliable evidence of discrimination on the basis of pitch-difference if the animal can be brought gradually to the point where it will be affected by the stimulus.

SUMMARY

The foregoing experiments have failed in showing to what extent the dog is sensitive to difference of pitch. They have not established that he is sensitive to pitch-difference at all. While they have not proved the contrary, they should have shown that we are not safe in accepting the assertion of Kalischer, Rothmann and Swift, that the dog has an exceedingly fine absolute pitch sensitivity. These experiments have shown that the evidence submitted to date does not warrant such a conclusion. They have also shown some of the difficulties in the way of making satisfactory tests on audition in animals, and should have demonstrated what is and what is not a reliable method of investigation in this field. It should also be

apparent that in using animals for operations to settle questions of cerebral localization, it is necessary to use methods of training far more complicated than many physiologists appear to appreciate. Certainly the remarkable variation in the findings of the investigators whose work has been considered in the foregoing pages, may be readily explained by reference to their methods of training.

APPENDIX I

On page 5 the reader was referred to a daily record made by one of my animals on pitch-discrimination which is reproduced below.

PROBLEM 6, DOG 3, DECEMBER 14, 1911

Trial	Proper choice	Actual choice
1	R	R
2	L	L
3	R	R
4	L	L
5	R	R
6	R	L
7	R	R
8	L	L
9	R	R
10	L	L
11	L	R
12	R	L
13	R	R
14	L	L
15	R	R

Correct reactions	12
Incorrect reactions	3
Total	15
Percentage of accuracy	80

Even superficial inspection will show that this animal was merely choosing the right and the left food-compartments alternately regardless of the stimulus given. She developed much more elaborate position-habits than this. This record is shown merely to call attention to the necessity of having several consecutive perfect daily records, with the order of presentation and secondary criteria under control, before assuming that the animal has learned to discriminate.

APPENDIX II

CONTROL EXPERIMENT ON DISCRIMINATION TO NOISE, AFTER LEARNING

In commenting on Rothmann's experiment (page 14) I emphasized the desirability of having all stimuli presented when the animal is occupying the same position relative to the food. The following record is more spectacular than some others which my animals have made, but I have noted numerous other instances which illustrate the point almost as well.

It has already been said that this dog had learned the problem. On the second day of her training she showed an invariable tendency to turn to the right food-compartment (F′). Each time on the second day and twice on the third day, immediately after the animal had made the wrong turn, the experimenter sounded the left buzzer the second time. When the control-test was made, eight days had elapsed since this had been done. This day's record, which follows, shows clearly how strong and persistent was the association.

Problem 8, Dog 2, April 22, 1912

Trial	Proper choice	Actual choice
1	R	R†
2	R	R†
3	L	L
4	R	R†
5	L	L
6	L	L
7	R	L*
8	L	L
9	R	L*
10	R	L*
11	R	L*
12	L	L
13	R	L*
14	R	R†
15	L	L

Correct reactions...........	10
Incorrect reactions.........	5
Total..................	15
Percentage of accuracy.....	$66\frac{2}{3}$

* Turned R; operator sounded (r) buzzer again; dog reversed choice.
† Stimulus presented only once.

II. COMPARISON OF LEARNING-TIME AND LEARNING-METHODS IN BLIND AND IN NORMAL DOGS

The behavior of the two temporarily blind dogs used in the experiments already described suggested another problem for which the animals could be used as material. It is evident that an animal trained to open the "puzzle-box" used by Thorndike [1] in work with cats and other animals and by Watson [2] and others in experiments on the white rat, must make a complicated and delicate adjustment in a minimal time. It should be interesting to ascertain to what extent the dog makes use of vision in making this adjustment; and to compare the methods employed by blind and by normal dogs in learning such problem. Further, these dogs had learned to behave in their ordinary environment practically as normal dogs, although none of their "spatial world" was "visual space." The "Molyneaux problem" is at once suggested, and it becomes of interest to note any changes in behavior concurring with the formation of a world of visual space.

Six food-boxes were constructed for this problem of 2″ x 2″ white pine framework covered with steel woven wire having a mesh about 1 cm. square. These boxes were each 30″ wide, 24″ long and 24″ high. A door 12″ x 12″ was cut in one of the 30″ x 24″ sides, and hung so as to be opened by a coiled spring when the latch was released. A sketch of one of these boxes is shown in Figure 4. The boxes will hereafter be referred to by number. The kind of latch and hanging of the door to each box is shown below.

Box No.	Kind of latch	Door opening
1	spoon-dip	inward
2	turn-button	outward
3	lift-bar	"
4	slide-bar	"
5	peg-in-hole	"
6	bobbin-string	inward

The program was to have each dog while yet blind learn a separate set of three boxes; then to note what disturbance, if any, followed total darkening of the room in which the work

[1] THORNDIKE, E. L. Animal Intelligence.
[2] WATSON, JOHN B. Animal Education.

had been learned; to note disturbances resulting from turning the boxes 90°, 180° and 270° respectively from the first position; and to make a retention-test after sixty days of rest. The dog's eyes were then to be opened. After recovery they were to be given their old problem boxes, for the purpose of noting any change in method that might take place; then each dog was to be made to learn the three problem-boxes which the other dog had learned while blind. The last part of this test was not carried out on Dogs 1 and 2, since neither showed enough evidence of vision to warrant the continuation of the experiment.

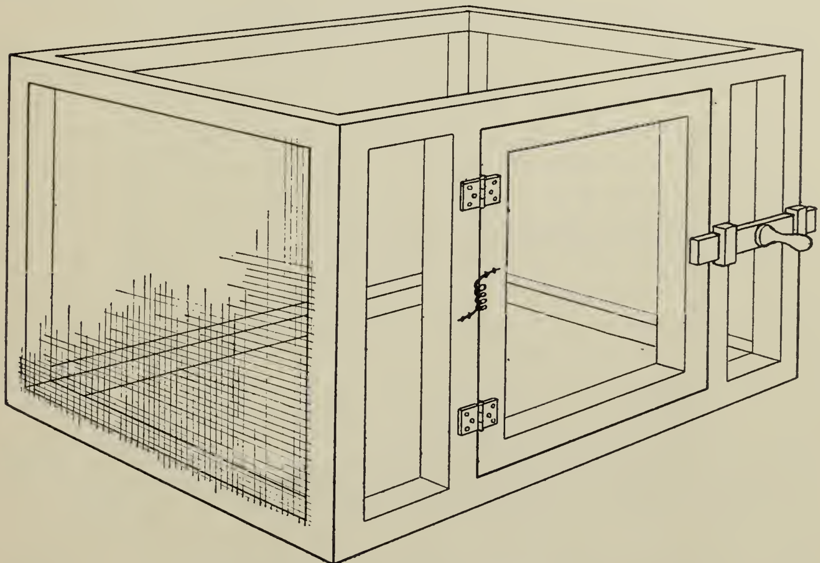


FIGURE 4—Sketch of problem-box 4

As to the animals used, Dogs 1 and 2, the temporarily blind females used in the work on audition, have already been described on p. 20. Dog 5 was a male of mixed breed—a cross between the bull-terrier and the black-and-tan—and was unusually quick, active and strong. He performed many tricks, among them jumping, catching a ball, etc., with great skill. Dogs 6, 7 and 8 were the offspring of Dog 5 and Dog 2. They were all males, littered June 1, 1911, in the psychological laboratory of the University of Chicago. Dog 6 was normal and cowardly.

Dogs 7 and 8 were rendered temporarily blind by the same method as that used on Dogs 1 and 2. Dr. Henry Dick, of the department of pathology of the University of Chicago, kindly performed the operation when the puppies were seven days old. Dog 7 was unusually large, but not clumsy. Despite his blindness he was able by reason of his fierceness and strength to maintain leadership of the eight dogs with which he was allowed to run. Dog 8 was small and decidedly of the terrier type. He was rather timid among the other dogs, and even in the laboratory his movements were deliberate. It should be said, however, that all the animals took readily to training of this

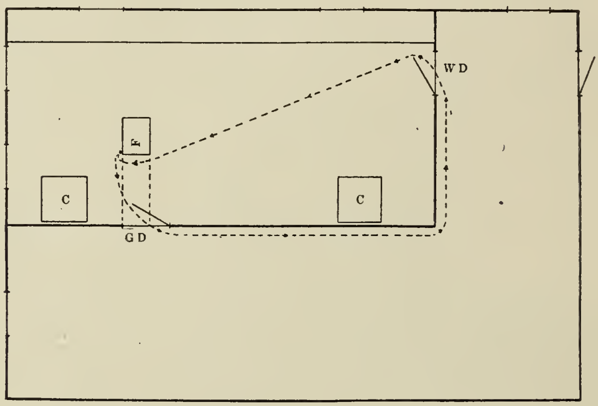


FIGURE 5—Floor plan of experimental-room. C, cages F, problem-box containing food; GD, glass exit door; WD, wooden entrance door; dotted line, habitual path of animal. Experimenter's station, outside room, by GD.

kind. They were fed once a day—during the daily test. Immediately after the series was completed for the day, each animal was allowed as much food as it would take. All the animals were in excellent, thrifty condition throughout the experimentation.

Dogs 1 and 2 were between four and five years old when they were introduced to this problem. Dog 5, a stray, was about one year of age. Dogs 6, 7 and 8 were five and one-half months old when work with them was begun. The experiments made on Dogs 1, 2 and 5 were between November 5, 1910 and March 20, 1911. Those made on Dogs 6, 7 and 8 were between November 15, 1911 and July 12, 1912.

The following method was employed in training: A room, the floor-plan of which is shown in Fig. 4, was partitioned off from a larger room, from which the observations were made The problem-box F was placed in the smaller room, sixteen feet from the wooden door W.D. in the diagram, and about four feet directly opposite the glass door G.D. where the operator stood. Food was placed in the problem-box, the door of which was left open for the first week. The animal which was left to run free in the larger room, was admitted through the wooden door W.D. to the smaller room, where it had already become accustomed to being fed. The wooden door opened by the operator pulling a rope running from it to the glass door, and was closed by a weight and pulley system after the animal had passed through. After the animal had obtained the food in the problem-box, it was released from the smaller room into the larger through the glass door G.D. Food was again placed in the problem-box and the animal readmitted through the wooden door as before. Every animal soon acquired a fixed path to and from the problem-box, which path is indicated by the dotted line and arrows in Fig. 4. By this method of training previous to the setting of the problem the animal's problem was simplified. There was no apparent disturbance from the operator's movements: as soon as the animal was released through the glass door G.D. it immediately ran to the wooden door and awaited readmission to the animal room; it was out of sight of the operator and wasted no time in trying to get food in other than the prescribed way. When the animal was presented to the problem-box the operator was out of the room, and in the actual experimentation, out of sight of the animal, as the larger room was darkened in the earlier stages of each new problem.

This general mode of procedure—the food-motive and the removal of the operator from the animal's immediate presence—has of course been used before by other experimenters and on other animals. It differs from the method of Thorndike. In his work the animals were confined in the puzzle box, it being assumed that the animal's desire to escape would be a satisfactory motive to bring about the opening of the box. The animals were dropped into the box from the top. Some of them being more nervous or timid than others, were more

greatly disturbed by this procedure; some apparently became frantic; the movements of others were inhibited probably from "fright." Still others, more quiet, became satisfied after making a few unsuccessful attempts to escape, and remained quiet for a long time. The defects n this method are obvious, and the advantages of the one adopted for this work will become more apparent when the animals' behavior is discussed.

After the animal had been fed from the open box for a week or more, one day's work was done with the door of the problem-box wedged open by only about two inches from the jamb. The dog had to force it open in some way in order to get the food. This was found necessary in the preliminary experiments because the animals would not try to open the box when it was latched. After sniffing and scratching lightly about the corner they would lie down for hours. This behavior lasted through three successive days and the experimenter believed that prolonging the animals' hunger could produce only harmful results. After one day of feeding from the partly closed box every animal quickly attacked the problem of opening the latched door.

Time was taken at each trial after the box was first latched. The record was of the number of seconds required for the animal to obtain the food after it had crossed the dotted line from the glass door to the corner of the problem-box. This point was chosen rather than the wooden door, because Dogs 1 and 2 were much heavier and slower of movement than any of the other dogs, and required one to two seconds more time to reach the problem-box from the wooden door, although their movements in opening the boxes were as swift and as accurate as were those of any of the other dogs. There was one disadvantage, however, in that it was difficult to tell within one-half second or so when the dog had crossed this line if the work was done in total darkness. Time was taken with an ordinary stop-watch. This records to 0.2 seconds. Fractional readings less than 0.5 seconds were disregarded; those greater than 0.5 second were counted one second. Some experimenters attempt to take time-readings in this way as closely as 0.2 seconds, and consider the fractions at full value in computing their results. In such work as this, however, the writer believes such a record shows an apparent accuracy which is not real. The experimenter's reaction-time will show considerable

variation; the ordinary cheap laboratory stop-watch may show a difference of 0.2 second in the time necessary to start and to stop it respectively; the instrument gets out of order easily, and the experimenter does not react to a movement of the animal which is absolutely constant for any two reactions. Further the writer does not believe a difference of 0.2 seconds to be significant in an animal's making so complicated a reaction as that of opening the problem-box.

In the experiments on Dogs 1, 2 and 5, twenty trials a day were allowed. Dogs 6, 7 and 8 were allowed only ten daily trials. It will be seen from the records that the dogs allowed only ten trials a day required fewer trials and in some cases even fewer days than did the animals given twenty trials under similar conditions. This may be explainable by the fact that after a certain amount of work has been done an animal may tend to become careless, through fatigue perhaps, and will relapse into errors, which, becoming habitual, persist for a considerable time. The tables show the distribution of errors made in this work by each dog, according to the place in the animal's daily series. It would be interesting to know just what is the optimal number of daily trials which should be allowed to a dog as compared with other animals in order to economize the learning process to the greatest degree.

TABLE 1

Learning Records on Box 1

Dog 1 (Blind ♀)

Problem 1

Day / Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total errors
1	1	1	1	1	1	1	1	1			1			1		1						11
2	1	1	1	1	1	1		1		1		1	1	1		1						12
3	1	1	1	1	1			1	1		1	1	1	1								11
4	1	1	1	1	1			1			1	1	1	1								10
5	1	1	1	1	1	1		1		1	1	1	1	1								12
6	1	1	1	1	1	1		1		1		1	1	1								11
7	1	1	1	1	1	1	1	1				1	1									10
8	1	1	1	1	1	1					1		1	1		1		1				11
9	1	1	1	1	1	1					1	1	1	1								10
10	1	1	1	1	1	1	1			1	1	1	1		1							12
11	1	1	1	1	1	1		1			1	1	1	1								11
12	1	1	1	1	1	1						1	1	1	1	1						11
13	1	1	1	1	1	1			1	1	1	1	1		1							12
14	1	1	1	1		1		1	1	1				1	1	1						11
15	1	1	1	1	1	1	1			1		1				1						10
16	1	1	1	1			1	1		1	1	1	1									10
17	1	1	1	1		1	1		1	1			1				1					10
18	1	1	1		1	1	1		1	1			1		1							10
19	1	1	1			1	1	1		1		1	1		1							10
20	1	1	1		1	1		1		1		1	1		1		1					11
Total errors	20	20	20	17	16	17	8	12	5	12	10	15	17	11	7	6	2	1	0	0	0	216
% Error...	100	100	100	85	80	85	40	60	25	60	50	75	85	55	35	30	10	5	0	0	0	
% Accuracy	0	0	0	15	20	15	60	40	75	40	50	25	15	45	65	70	90	95	100	100	100	
Av. time...	...	...	...	...	5.0	10.4	2.7	2.9	2.1	1.5	1.5	1.9	1.9	1.5	1.3	1.2	1.1	1.1	1.0	1.0	1.0	

TABLE 1—Continued

LEARNING RECORDS ON BOX 1

DOG 5 (NORMAL ♂)

Problem 1

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	Total errors
1	1	1	1	1	1								5
2	1	1	1	1									4
3	1	1	1			1							4
4	1	1	1										3
5	1	1	1	1									4
6	1	1	1										3
7	1	1	1	1									4
8	1	1	1										3
9	1	1	1		1								4
10	1	1	1	1				1					5
11	1	1	1	1	1								5
12	1	1	1	1									4
13	1	1	1	1	1	1	1		1				8
14	1	1	1		1								4
15	1	1	1	1									4
16	1	1	1	1	1		1						6
17	1	1	1	1									4
18	1	1	1										3
19	1	1	1	1	1								5
20	1	1	1		1								4
Total errors	20	20	20	12	8	2	2	1	1	0	0	0	86
% Error...	100	100	100	60	40	10	10	5	5	0	0	0	
% Accuracy	0	0	0	40	60	90	90	95	95	100	100	100	
Av. time...	...	...	20.0	5.0	1.5	1.1	1.0	1.0	1.0	1.0	1.0	10.	

DOG 6 (NORMAL ♂)

Problem 2

Days..... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total errors
1	1			1	1	1												1					5
2		1			1		1	1		1	1	1											7
3	1								1	1	1				1								5
4	1				1														1				3
5	1				1																		2
6	1				1	1						1	1				1						6
7	1	1			1		1								1		1	1					7
8	1	1	1	1			1	1		1		1	1				1						10
9		1		1		1		1	1			1		1									7
10	1		1					1															3
Total errors	8	4	2	3	6	3	3	4	2	3	2	4	2	1	2	0	3	2	1	0	0	0	55
% Error...	80	40	20	30	60	30	30	40	20	30	20	40	20	10	20	0	30	20	10	0	0	0	
% Accuracy	20	60	80	70	40	70	70	60	80	70	80	60	80	90	80	100	70	80	90	100	100	100	
Av. time...	3.3	1.8	1.2	1.4	1.9	1.2	1.2	1.0	1.3	1.0	1.0	1.1	1.0	1.0	1.2	1.0	1.0	1.1	1.0	1.0	1.0	1.0	

DOG 7 (BLIND ♂)

Problem 2

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Total errors
1	1	1	1	1			1			1				1	1	1										9
2	1	1		1							1		1	1		1						1				8
3	1	1											1	1	1	1	1				1					8
4	1	1	1			1	1	1		1	1	1	1	1	1	1	1		1							15
5	1	1	1		1	1		1	1	1				1		1					1					11
6	1	1	1	1	1					1	1		1					1								9
7	1	1	1	1	1						1	1			1											8
8	1		1	1				1	1					1	1											7
9	1				1		1			1	1	1		1					1							8
10	1		1		1	1		1		1	1			1	1	1	1		1							12
Total errors	10	7	7	5	5	3	3	4	2	6	6	3	4	8	6	6	3	1	3	0	2	1	0	0	0	95
% Error...	100	70	70	50	50	30	30	40	20	60	60	30	40	80	60	60	30	10	30	0	20	10	0	0	0	
% Accuracy	0	30	30	50	50	70	70	60	80	40	40	70	60	20	40	40	70	90	70	100	80	90	100	100	100	
Av. time...	4.6	6.5	3.1	1.3	1.9	1.6	1.3	1.1	1.1	1.3	1.6	1.4	2.0	2.5	1.7	1.3	1.3	1.1	1.2	1.0	1.0	1.1	1.0	1.0	1.0	

TABLE 1—Continued

LEARNING RECORD ON BOX 1

DOG 8 (BLIND ♂, AFTER OPERATION)

Problem 5

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total errors
1	1	1	1	1	1		1	1			1							8
2	1	1		1			1	1		1		1						7
3	1	1		1		1	1		1									6
4	1	1	1	1	1				1		1		1					8
5	1	1	1		1		1			1	1							7
6		1	1		1	1	1	1			1							7
7	1		1			1	1	1		1	1		1					8
8	1		1	1			1				1			1				6
9	1	1		1		1		1		1		1						7
10	1	1	1	1	1	1		1	1	1		1						10
Total errors	9	8	7	7	5	5	7	6	3	5	6	3	2	1	0	0	0	74
% Error...	90	80	70	70	50	50	70	60	30	50	60	30	20	10	0	0	0	
% Accuracy	10	20	30	30	50	50	30	40	70	50	40	70	80	90	100	100	100	
Av. time...	...	...	18.0	5.1	4.2	3.1	3.5	2.4	2.6	2.0	2.1	1.4	1.1	1.2	1.0	1.0	1.0	

TABLE 2

LEARNING RECORD ON BOX 2

DOG 2 (BLIND ♀)

Problem 2

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total errors
1	1	1	1	1	1	1	1	1	1	1		1		1	1						13
2	1	1	1	1	1	1	1	1	1	1		1									11
3	1	1	1	1		1		1	1	1		1				1					10
4	1	1	1	1	1	1	1	1	1						1						10
5	1	1	1	1	1	1	1		1	1				1	1						11
6	1	1	1	1	1			1	1	1		1		1							10
7	1	1	1	1	1	1	1	1	1	1					1						11
8	1	1	1	1	1	1	1	1	1	1				1	1						12
9	1	1	1	1	1	1		1	1	1		1		1							11
10	1	1	1	1	1	1	1	1	1	1											10
11	1	1	1	1	1	1	1	1													8
12	1	1	1	1	1	1									1						7
13	1	1	1	1	1	1	1					1			1		1				10
14	1	1	1	1	1	1			1	1	1			1	1						11
15	1	1	1	1	1	1	1	1	1					1	1						11
16	1	1	1	1	1	1	1	1	1					1	1	1					12
17	1	1	1	1	1	1	1	1	1	1		1		1	1						13
18	1	1	1	1	1	1	1	1	1					1	1						11
19	1	1	1	1	1	1	1	1	1				1	1	1						12
20	1	1	1	1	1	1	1	1	1		1	1		1	1						13
Total errors	20	20	20	20	19	19	15	16	17	11	2	8	1	12	14	2	1	0	0	0	217
% Error...	100	100	100	100	95	95	75	80	85	55	10	40	5	60	70	10	5	0	0	0	
% Accuracy	0	0	0	0	5	5	25	20	15	45	90	60	95	40	30	90	95	100	100	100	
Av. time...	3.3	2.6	3.4	3.2	3.1	2.7	2.1	2.3	1.2	1.8	1.3	1.6	1.6	1.6	2.3	1.6	1.1	1.2	1.1	1.0	

TABLE 2—Continued

LEARNING RECORDS ON BOX 2

DOG 5 (NORMAL ♂)

Problem 4

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total errors
1	1	1	1	1	1	1	1	1	1						9
2	1	1	1	1	1	1	1	1	1						9
3	1	1	1	1	1	1	1	1							8
4	1	1	1	1	1	1	1	1							8
5	1	1	1	1	1	1	1	1							8
6	1	1	1	1	1	1	1	1			1				9
7	1	1	1	1	1	1	1	1			1				9
8	1	1	1	1	1	1	1		1						8
9	1	1	1	1	1	1	1	1							8
10	1	1	1	1	1	1	1	1							8
11	1	1	1		1	1	1	1							7
12	1	1	1	1	1	1	1	1							8
13	1	1	1	1		1	1								6
14	1	1	1	1	1	1	1								7
15	1	1	1	1		1	1	1							7
16	1	1	1	1	1	1	1								7
17	1	1	1	1	1	1	1		1		1				9
18	1	1	1	1		1	1		1		1				8
19	1	1	1	1	1		1			1					7
20	1	1	1	1	1		1		1						7
Total errors	20	20	20	19	17	18	20	12	6	1	4	0	0	0	157
% Error...	100	100	100	95	85	90	100	60	30	5	20	0	0	0	
% Accuracy	0	0	0	5	15	10	0	40	70	95	80	100	100	100	
Av. time...	2.5	2.2	2.3	1.9	2.2	1.2	1.4	1.2	1.1	1.1	1.0	1.0	1.0	1.0	

DOG 6 (NORMAL ♂)

Problem 5

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total errors
1		1	1		1	1		1								5
2	1	1	1		1	1	1					1				7
3	1	1		1	1	1			1	1						7
4		1			1											2
5	1	1	1	1	1		1									6
6	1	1		1	1	1	1									6
7	1	1	1	1		1			1							6
8	1		1		1	1					1					5
9	1	1	1	1												4
10	1	1	1	1			1									5
Total errors	8	9	7	6	7	6	4	1	2	1	1	1	0	0	0	53
% Error...	80	90	70	60	70	60	40	10	20	10	10	10	0	0	0	
% Accuracy	20	10	30	40	30	40	60	90	80	90	90	90	100	100	100	
Av. time...	3.0	4.1	3.6	5.0	3.1	2.8	3.0	1.9	1.2	1.0	1.1	1.0	1.0	1.0	1.0	

DOG 7 (BLIND ♂, AFTER OPERATION)

Problem 5

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total errors
1	1	1	1	1	1	1		1							7
2	1	1	1	1	1		1			1	1				8
3	1	1		1			1		1	1					6
4	1	1	1				1								4
5	1	1	1	1	1	1	1		1						8
6	1	1		1	1		1								5
7	1		1	1	1		1								5
8	1		1	1	1	1		1							6
9	1	1	1		1			1							5
10	1	1			1	1									4
Total errors	10	8	7	7	8	4	6	3	2	2	1	0	0	0	58
% Error...	100	80	70	70	80	40	60	30	20	20	10	0	0	0	
% Accuracy	0	20	30	30	20	60	40	70	80	80	90	100	100	100	
Av. time...	22.0	9.1	4.7	3.9	3.1	2.2	2.6	2.0	1.7	1.4	1.5	1.0	1.1	1.0	

TABLE 2—Continued
LEARNING RECORDS ON BOX 2
DOG 8 (BLIND ♂)
Problem 2

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	Total errors
1	1	1	1	1	1		1						6
2	1		1	1									3
3	1	1	1	1									4
4	1	1	1	1									4
5	1	1		1	1	1							5
6	1								1				2
7	1		1	1									3
8		1	1	1									3
9				1		1							2
10		1	1	1									3
Total errors	7	6	7	9	2	2	1	0	1	0	0	0	35
% Error...	70	60	70	90	20	20	10	0	10	0	0	0	
% Accuracy	30	40	30	10	80	80	90	100	90	100	100	100	
Av. time...	72.0	2.1	6.3	8.0	2.2	1.8	1.9	1.4	1.1	1.0	1.0	1.0	

TABLE 3
LEARNING RECORDS ON BOX 3
DOG 1 (BLIND ♀)
Problem 3

Days...... Trials	1	2	3	4	5	6	7	8	9	Total errors
1	1	1				1				3
2	1	1	1	1	1					5
3	1	1	1							3
4	1		1							2
5	1		1		1					3
6		1				1				2
7				1	1					2
8		1								1
9		1								1
10	1									1
11	1									1
12	1									1
13	1									1
14	1									1
15	1	1								2
16	1									1
17	1									1
18	1									1
19	1									1
20	1	1	1							3
Total errors	16	8	5	2	3	2	0	0	0	36
% Error...	80	40	25	10	15	10	0	0	0	
% Accuracy	20	60	75	90	85	90	100	100	100	
Av. time...	—	7.5	1.2	1.4	1.1	1.1	1.1	1.0	1.0	

TABLE 3—Continued

LEARNING RECORDS ON BOX 3

DOG 5 (NORMAL ♂)

Problem 3

Days...... Trials	1	2	3	4	5	6	Total errors
1	1						1
2	1	1					2
3	1	1	1				3
4	1		1				2
5	1						1
6	1						1
7	1						1
8	1						1
9	1						1
10	1						1
11	1	1					2
12	1						1
13	1						1
14	1						1
15	1						1
16	1						1
17							0
18							0
19		1					1
20							0
Total errors	16	4	2	0	0	0	22
% Error...	80	20	10	0	0	0	
% Accuracy	20	80	90	100	100	100	
Av. time...	2.5	1.1	1.0	1.0	1.0	1.0	

DOG 6 (NORMAL ♂)

Problem 4

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	Total errors
1	1	1	1	1			1			1				6
2	1	1	1	1	1	1	1		1					8
3	1		1		1	1								4
4	1				1	1				1				4
5	1	1	1	1	1			1						6
6	1		1		1	1	1	1						6
7		1	1		1			1						4
8	1	1	1	1										4
9	1	1	1	1		1								5
10	1	1	1	1										4
Total errors	9	7	9	6	6	5	3	3	1	2	0	0	0	51
% Error...	90	70	90	60	60	50	30	30	10	20	0	0	0	
% Accuracy	10	30	10	40	40	50	70	70	90	80	100	100	100	
Av. time...	2.5	1.7	1.4	1.4	1.2	1.3	1.5	1.1	1.3	1.0	1.0	1.0	1.0	

DOG 7 (BLIND ♂, AFTER OPERATION)

Problem 4

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total errors
1	1	1	1		1		1	1				1					7
2	1	1	1	1		1			1		1						7
3		1	1	1	1	1		1		1	1						8
4		1				1	1			1			1				5
5	1	1	1		1				1				1				6
6	1	1	1	1	1			1				1					7
7	1	1	1	1	1	1		1	1	1		1					10
8	1	1				1	1			1		1					6
9	1			1		1		1	1	1							6
10	1			1	1	1	1	1	1	1							8
Total errors	8	8	6	6	6	7	4	6	5	6	2	4	2	0	0	0	70
% Error....	80	80	60	60	60	70	40	60	50	60	20	40	20	0	0	0	
% Accuracy	20	20	40	40	40	30	60	40	50	40	80	60	80	100	100	100	
Av. time...	6.0	8.1	3.4	3.1	3.3	1.6	1.2	1.4	1.2	1.2	1.0	1.0	1.1	1.0	1.0	1.0	

TABLE 3—Continued

LEARNING RECORDS ON BOX 3

DOG 8 (BLIND ♂)

Problem 1

Days… / Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total errors
1	1	1	1	1	1			1								6
2	1	1	1	1	1											5
3	1	1		1	1	1	1									6
4	1	1	1			1		1								5
5	1	1	1	1		1	1			1						7
6	1	1	1	1	1											5
7	1	1	1	1	1	1	1	1			1					9
8	1	1	1	1	1	1		1								7
9	1	1	1	1	1							1				6
10	1	1	1	1	1	1		1	1							8
Total errors	10	10	9	9	8	6	3	5	1	1	1	1	0	0	0	64
% Error…	100	100	90	90	80	60	30	50	10	10	10	10	0	0	0	
% Accuracy	0	0	10	10	20	40	70	50	90	90	90	90	100	100	100	
Av. time…	—	—	24.7	5.1	3.1	2.6	2.1	2.1	1.3	1.5	1.4	1.0	1.0	1.0	1.0	

TABLE 4

LEARNING RECORDS ON BOX 4

DOG 2 (BLIND ♀)

Problem 1

Days… / Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Total errors
1	1	1	1	1	1	1	1	1	1					1	1				11
2	1	1	1	1	1	1	1		1	1									9
3	1	1	1	1	1	1	1	1			1				1				10
4	1	1	1		1	1	1	1	1	1									9
5	1	1	1	1	1	1	1		1				1						9
6	1	1	1	1	1	1	1	1	1	1									10
7	1	1		1	1	1	1	1	1										8
8	1	1	1	1	1	1			1	1				1					9
9	1	1		1	1	1			1										6
10	1	1		1	1	1	1	1	1										8
11	1	1	1	1	1	1	1	1	1			1							10
12	1	1	1	1	1	1			1										7
13	1	1	1	1	1	1	1	1	1		1								10
14	1	1	1		1	1	1	1	1	1		1							10
15	1	1		1	1	1		1	1			1							8
16	1	1		1	1	1			1	1									7
17	1	1			1	1		1	1		1								7
18	1	1			1	1	1	1	1	1									8
19	1	1	1	1	1	1	1		1										8
20	1	1	1	1	1	1	1	1	1	1									10
Total errors	20	20	13	16	20	20	14	13	19	8	3	3	1	2	2	0	0	0	174
% Error…	100	100	65	80	100	100	70	65	95	40	15	15	5	10	10	0	0	0	
% Accuracy	0	0	35	20	0	0	30	35	5	60	85	85	95	90	90	100	100	100	
Av. time…	—	—	12.0	3.5	3.3	3.2	1.8	2.1	2.1	2.4	1.1	1.3	1.7	1.3	1.3	1.1	1.0	1.0	

TABLE 4—Continued

Learning Records on Box 4

Dog 5 (Normal ♂)

Problem 2

Days…… Trials	1	2	3	4	5	6	7	8	9	10	11	Total errors
1	1	1	1	1	1	1	1	1				8
2	1	1	1	1	1	1						6
3	1	1		1								3
4	1		1	1		1						4
5	1	1		1		1						4
6	1	1		1								3
7	1	1		1	1							4
8	1	1	1	1								4
9	1	1	1	1		1						5
10	1	1		1								3
11	1	1	1	1		1						5
12	1	1	1	1	1							5
13	1	1	1	1	1							5
14	1	1	1	1		1						5
15	1	1	1	1	1	1						6
16	1	1	1	1	1	1		1				7
17	1	1	1	1	1							5
18	1	1										2
19	1	1	1		1							4
20	1	1	1									3
Total errors	20	19	14	17	9	9	1	2	0	0	0	91
% Error…	100	95	70	85	45	45	5	10	0	0	0	
% Accuracy	0	5	30	15	55	55	95	90	100	100	100	
Av. time…	—	—	31.0	8.0	11.8	1.3	1.1	1.3	1.0	1.0	1.0	

Dog 6 (Normal ♂)

Problem 1

Days…… Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Total errors
1	1	1	1			1	1	1	1	1	1	1	1	1		1						13
2	1	1		1	1		1	1	1	1	1		1		1		1					12
3	1	1	1	1	1	1	1	1		1												9
4	1	1		1	1		1	1	1		1	1	1	1								11
5	1	1			1	1	1	1				1		1			1					9
6	1	1	1		1	1	1	1		1	1		1	1		1		1				13
7	1	1	1	1	1	1	1	1	1	1		1	1	1			1					14
8	1	1		1	1	1	1	1		1			1	1		1	1					12
9	1	1	1		1	1	1	1	1	1	1			1			1					12
10	1	1	1	1		1	1			1				1								8
Total errors	10	10	6	6	8	8	10	9	5	8	5	4	6	8	1	3	5	1	0	0	0	113
% Error…	100	100	60	60	80	80	100	90	50	80	50	40	60	80	10	30	50	10	0	0	0	
% Accuracy	0	0	40	40	20	20	0	10	50	20	50	60	40	20	90	70	50	90	100	100	100	
Av. time…	—	—	2.9	2.3	2.6	5.0	1.7	3.3	2.2	2.6	1.9	1.5	2.5	2.0	1.3	1.3	1.4	1.1	1.0	1.0	1.0	

Dog 7 (Blind ♂)

Problem 1

Days…… Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Tota errors
1	1	1	1	1	1	1	1	1		1	1	1						11
2	1	1	1	1	1	1	1		1	1			1	1				11
3	1	1	1	1	1		1		1				1					8
4	1	1	1	1	1		1		1	1								8
5	1	1	1	1	1		1		1									7
6	1	1	1	1	1				1			1						7
7	1	1		1	1	1	1		1									7
8	1	1	1	1	1		1		1		1							8
9	1	1	1	1	1		1	1				1						8
10	1	1	1			1	1	1			1							7
Total errors	10	10	9	9	9	4	9	3	7	3	3	3	2	1	0	0	0	82
% Error…	100	100	90	90	90	40	90	30	70	30	30	30	20	10	0	0	0	
% Accuracy	0	0	10	10	10	60	10	70	30	70	70	70	80	90	100	100	100	
Av. time…	—	—	22.8	3.4	3.8	2.7	4.4	2.6	2.3	1.9	1.2	1.7	1.3	1.1	1.0	1.0	1.0	

TABLE 4—Continued

Learning Records on Box 4

Dog 8 (Blind ♂, After Operation)

Problem 4

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total errors
1	1	1	1			1			1						5
2	1	1	1	1	1	1		1							7
3	1		1	1	1		1				1				6
4	1	1	1	1			1			1					6
5			1	1	1			1							4
6		1		1		1									3
7	1	1		1											3
8		1	1			1									3
9	1	1	1			1	1								5
10	1	1	1												3
Total errors	7	8	8	6	3	5	3	2	1	1	1	0	0	0	45
% Error...	70	80	80	60	30	50	30	20	10	10	10	0	0	0	
% Accuracy	30	20	20	40	70	50	70	80	90	90	90	100	100	100	
Av. time...	4.0	3.4	2.8	2.2	2.6	1.9	1.4	1.6	1.1	1.3	1.0	1.0	1.0	1.0	

TABLE 5

Learning Records on Box 5

Dog 1 (Blind ♀)

Problem 2

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total errors
1	1	1	1	1	1	1	1		1	1		1								10
2	1	1	1	1			1				1									6
3	1	1	1	1	1	1	1			1										8
4	1	1	1	1	1	1	1	1	1		1									10
5	1	1	1	1	1			1	1		1									8
6	1	1	1		1										1					5
7	1	1	1		1															4
8	1	1		1	1			1	1			1								7
9	1	1	1							1										4
10	1	1	1	1						1										5
11	1	1	1				1		1				1							6
12	1	1	1	1		1	1	1	1	1	1				1					11
13	1	1	1					1	1	1				1		1				8
14	1	1	1	1	1			1	1	1	1									9
15	1	1		1							1		1							5
16	1	1	1	1	1		1	1												7
17	1	1	1		1	1		1	1	1		1								9
18	1	1	1	1		1			1	1										7
19	1	1	1	1	1		1	1	1	1	1	1								11
20	1	1	1	1	1	1	1	1	1	1										10
Total errors	20	20	18	14	12	7	9	10	12	11	7	4	2	1	2	1	0	0	0	150
% Error...	100	100	90	70	60	35	45	50	60	55	35	20	10	5	10	5	0	0	0	
% Accuracy	0	0	10	30	40	65	55	50	40	45	65	80	90	95	90	95	100	100	100	
Av. time...	...	...	3.8	2.5	2.4	1.5	1.7	3.3	2.1	1.9	1.6	1.5	1.2	1.1	1.1	1.1	1.0	1.0	1.0	

TABLE 5—Continued

LEARNING RECORDS ON BOX 5

DOG 5 (NORMAL ♂)

Problem 5

Days...... Trials	1	2	3	4	5	6	7	8	9	10	Total errors
1	1	1	1	1							4
2	1		1				1				3
3	1	1	1	1							4
4	1	1	1								3
5	1										1
6	1	1	1	1							4
7	1	1	1		1						4
8	1	1		1							3
9	1	1									2
10	1	1	1								3
11	1	1	1								3
12	1	1	1								3
13	1	1	1		1	1					5
14	1	1									2
15	1										1
16	1		1				1				3
17		1	1								2
18		1									1
19		1		1							2
20	1	1									2
Total errors	17	16	12	5	2	1	2	0	0	0	55
% Error...	85	80	60	25	10	5	10	0	0	0	
% Accuracy	15	20	40	75	90	95	90	100	100	100	
Av. time..	—	3.3	2.5	2.0	1.2	1.2	1.0	1.0	1.0	1.0	

DOG 6 (NORMAL ♂)

Problem 6

Days...... Trials	1	2	3	4	5	6	7	8	9	10	Total errors
1	1	1	1				1				4
2	1	1		1							3
3	1			1							2
4			1								1
5	1	1					1				3
6	1	1			1						3
7		1									1
8	1	1	1								3
9	1	1	1								3
10	1										1
Total errors	8	7	4	2	1	0	2	0	0	0	24
% Error...	80	70	40	20	10	0	20	0	0	0	
% Accuracy	20	30	60	80	90	100	80	100	100	100	
Av. time...	3.8	2.9	2.7	1.6	1.1	1.0	1.3	1.0	1.0	1.0	

DOG 7 (BLIND ♂, AFTER OPERATION)

Problem 6

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	Total errors
1	1	1	1	1			1					5
2	1	1	1	1		1		1				6
3	1	1	1									3
4	1	1		1								3
5	1				1							2
6	1		1									2
7	1	1	1		1	1						5
8	1	1	1									3
9	1	1	1									3
10	1	1		1		1						4
Total errors	10	8	7	4	2	3	1	1	0	0	0	36
% Error...	100	80	70	40	20	30	10	10	0	0	0	
% Accuracy	0	20	30	60	80	70	90	90	100	100	100	
Av. time...	...	...	7.0	2.6	2.5	1.9	2.2	1.6	1.4	1.3	1.0	

TABLE 5—Continued

LEARNING RECORDS ON BOX 5

DOG 8 (BLIND ♂)

Problem 3

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	Total errors
1	1	1	1	1		1		1						6
2	1	1	1	1					1					5
3	1	1	1	1	1									5
4	1	1	1		1	1	1							6
5	1	1	1		1	1	1			1				7
6	1	1	1			1								4
7	1	1	1	1				1						5
8	1	1	1	1				1						5
9	1	1		1	1	1		1						6
10	1	1	1		1	1	1							6
Total errors	10	10	9	6	5	6	3	4	1	1	0	0	0	55
% Error...	100	100	90	60	50	60	30	40	10	10	0	0	0	
% Accuracy	0	0	10	40	50	40	70	60	90	90	100	100	100	
Av. time...	——	——	5.8	4.1	2.9	2.5	2.3	2.7	2.0	1.8	1.9	1.8	1.5	

TABLE 6

LEARNING RECORDS ON BOX 6

DOG 2 (BLIND ♀)

Problem 3

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total errors
1	1	1	1	1		1	1	1	1	1	1	1					11
2	1	1	1	1	1	1			1	1	1						9
3	1	1		1	1	1	1	1	1								8
4	1	1	1	1	1	1	1		1				1				9
5	1	1	1	1	1	1	1	1	1		1						10
6	1	1		1		1	1	1	1	1							8
7		1	1	1		1	1	1			1						7
8	1	1	1	1	1	1	1	1		1							9
9	1	1		1	1			1		1							6
10		1	1	1	1		1	1		1							7
11		1	1	1	1	1	1		1	1	1						9
12		1	1	1	1	1				1	1						7
13	1	1	1		1	1	1		1	1	1	1					10
14	1	1	1	1	1	1	1			1		1					9
15	1	1	1	1	1	1	1			1			1				9
16	1	1		1	1		1			1							6
17	1	1	1	1	1	1			1	1							8
18	1	1	1	1	1	1	1		1	1							9
19	1	1	1	1			1	1	1	1							8
20	1	1	1	1	1	1	1		1	1							9
Total errors	16	20	16	19	16	16	16	9	12	16	7	3	2	0	0	0	168
% Error...	80	100	80	95	80	80	80	45	60	80	35	15	10	0	0	0	
% Accuracy	20	0	20	5	20	20	20	55	40	20	65	85	90	100	100	100	
Av. time...	...	8.3	8.3	4.8	4.3	2.9	2.6	2.7	1.6	2.1	1.9	1.6	1.3	1.3	1.0	1.0	

TABLE 6—Continued

LEARNING RECORDS ON BOX 6

DOG 5 (NORMAL ♂)

Problem 6

Days...... Trials	1	2	3	4	5	6	7	8	9	10	Total errors
1	1		1								2
2	1	1			1						3
3	1					1					2
4	1	1		1							3
5	1		1								2
6	1	1	1		1		1				5
7	1	1				1					3
8		1		1							2
9		1	1		1						3
10	1	1		1							3
11		1									1
12		1	1	1	1		1				5
13											0
14											0
15	1	1		1		1					4
16	1	1		1		1					4
17		1	1								2
18		1	1		1						3
19		1	1	1		1					4
20		1	1		1						3
Total errors	10	15	9	7	6	5	2	0	0	0	54
% Error...	50	75	45	35	30	25	10	0	0	0	
% Accuracy	50	25	55	65	70	75	90	100	100	100	
Av. time...	—	2.4	1.8	1.6	1.3	1.2	1.2	1.0	1.0	1.0	

DOG 6 (NORMAL ♂)

Problem 3

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	Total errors
1	1	1	1	1	1							5
2	1	1	1	1	1		1					6
3	1	1		1								3
4	1	1		1	1	1						5
5	1	1	1		1		1					5
6	1	1	1		1							4
7	1	1	1									3
8	1	1	1		1		1	1				6
9	1	1		1		1						4
10	1	1	1	1								4
Total errors	10	10	7	6	6	2	3	1	0	0	0	45
% Error...	100	100	70	60	60	20	30	10	0	0	0	
% Accuracy	0	0	30	40	40	80	70	90	100	100	100	
Av. time...	4.5	1.9	2.2	1.7	2.0	1.1	1.3	1.0	1.5	1.0	1.0	

DOG 7 (BLIND ♂)

Problem 3

Days...... Trials	1	2	3	4	5	6	7	8	9	10	11	Total errors
1	1		1	1		1						4
2	1		1	1			1					4
3		1	1	1								3
4	1	1	1	1	1		1					6
5			1		1	1						3
6	1	1	1	1	1			1				6
7	1		1	1	1							4
8		1	1		1							3
9	1			1								2
10	1	1		1	1							4
Total errors	7	5	8	8	6	2	2	1	0	0	0	39
% Error...	70	50	80	80	60	20	20	10	0	0	0	
% Accuracy	30	50	20	20	40	80	80	90	100	100	100	
Av. time...	6.5	1.4	5.1	3.6	1.5	1.2	1.1	1.0	1.0	1.0	1.0	

TABLE 6—Continued

Learning Records on Box 6

Dog 8 (Blind ♂, After Operation)

Problem 6

Days / Trials	1	2	3	4	5	6	7	8	9	10	11	12	Total errors
1	1	1	1	1	1	1							6
2	1	1		1			1						4
3	1	1		1		1			1				5
4	1	1	1	1	1								5
5	1	1	1	1				1					5
6	1	1	1	1	1								5
7	1	1	1	1	1		1						6
8	1	1	1	1			1						5
9		1			1								2
10	1	1	1		1								4
Total errors	9	10	7	8	6	2	3	1	1	0	0	0	47
% Error...	90	100	70	80	60	20	30	10	10	0	0	0	
% Accuracy	10	0	30	20	40	80	70	90	90	100	100	100	
Av. time...	—	—	3.2	3.1	2.1	2.3	1.7	1.9	1.4	1.2	1.0	1.1	

Dogs 1 and 2 were operated on, 25 March, 1911, by Dr. Walter E. Dandy, of the Johns Hopkins Hospital. The operation was quite successful and healing followed without a trace of infection, but the corneas were found in bad condition. About three weeks after the operation Dog 2 received a scratch on the right cornea during a fight. This wound became infected and an abscess near the iris followed. So far as gross behavior indicated the animal was blind. Some tests were made on Dog 1 to discover whether the eyes were functioning. (Her corneas were not as clouded in appearance as were those of Dog 2; the pupils reacted well to light and she seemed in better general condition.)

Following the operation the dogs had been kept in a darkroom for ten days, until the wounds had entirely healed. Dog 1 was then taken into the laboratory and subjected to a few rough tests of the presence of vision. The experimenter stood at one end of a room forty feet long, holding food in his hand. The animal was held by another person at the opposite end of the room. When the experimenter called, the animal was released and came quickly to the experimenter for food. This was repeated four or five t'mes. Then a white pine board, two feet wide and eight feet long was set on edge and supported by props placed against the side away from the animal. When the dog was called she ran directly into the board. The position of the latter was changed four or five times but with no effect. A rope was then stretched across the room. The animal tripped over it each time, but after the fourth or fifth trial began

to hesitate when she approached the region where she had tripped before. Twice she jumped when she passed near where the rope had been stretched at the previous trial. The experiment was not continued further at that time, as prolongation of the tests seemed to be mere cruelty.

The same test was now given to Dog 5, the normal male. He always ran around or jumped over the board. The first trial given after the rope was stretched he tripped over the rope, turning a complete half-somersault. In subsequent trials he always jumped. The rope was held in the same place for three successive trials and then removed. In the next three successive trials when the animal reached the place where the rope had been stretched he jumped as he had jumped when the rope was there. The rope was then stretched again, two feet nearer the animal. This time the dog tripped by jumping too late—i.e., he jumped at about the same place as in the previous trials. In subsequent trials he always adjusted himself correctly.

The same tests were repeated on Dog 1 a week later. She avoided the board from the first, by means of what sense-avenues we of course do not know. She never succeeded in adjusting herself to the rope, however, always jumping too late or too soon.

These crude tests are further indication of the slight use of vision by the normal dog, and made it seem improbable that Dogs 1 and 2 would change their mode of attack on the problem-boxes because of the little vision they seemed to have. Accordingly it was decided to discontinue this work on them. It seemed questionable, however, whether better results might not be obtained by using animals which had not been kept in the blind state as long as had these. This was the reason for having the same operation performed on Dogs 7 and 8. I wish to say in this connection that our experience has not shown this operation useful for this work. It is not in itself cruel, and the only serious inconvenience which the blind puppies showed was their inability to compete with the normal puppies during the nursing period. The normal puppies would follow the mother into places in the animal's yard where the blind puppies would not go, and would often nurse when the blind puppies were not even present. After weaning, Dog 7 and

another blind litter brother not used in these experiments actually outgrew all the other members of the litter of seven. Dog 8, which was smaller at birth thrived well, while another blind male of the same litter, which was rather weakly from the beginning, died at four months of indigestion. There is no reason why a puppy which has undergone this operation should not live as thriftily and happily as a normal puppy if given proper care. But in clipping away enough of the edges of the eyelids to insure the formation of strong scar tissue some small glands are necessarily destroyed. While the dog is kept blinded, too, the small drain which is left at the corner of the eye is likely to become clogged and a slight infection may develop sufficiently to injure the cornea. The apparatus of accommodation may atrophy for want of use. A histological examination of the optic tracts of Dogs 1 and 2 will be made at some time in the future, in order to determine whether there was deterioration there.

Dogs 7 and 8 were operated on, 30 May, 1912, by Dr. Conrad Jacobson of the Johns Hopkins Hospital. Recovery was uneventful. The right cornea of Dog 8 was found considerably clouded, but cleared up to some degree in about two weeks after the operation. Dog 7 was apparently in good condition, although it was difficult to detect any change n his behavior. Substantially the same test was performed on him and Dog 8 as was made on Dog 1. There were no other persons present, so the obstruction, a board two feet wide and seven feet long, covered with white cheesecloth was placed directly in his habitual path from one room to another. Its position was changed after each trial. The door was opened by a weight-and-pulley system, and the operator released it just before calling the dog. Dog 8 collided once with the board, avoided it the next two consecutive times, collided the third and afterwards came into the room crouching and keeping to the wall. Dog 7 never bumped into the board. These tests were made fourteen days after the operation. Dog 8 avoided the board successfully in each of ten trials on the twenty-first day after the operation. In their other behavior absolutely no other change could be noted. Both of them in the blind state had found their way about the laboratory and yard. From about a month before the operation the animals were kept in a building at Home-

wood and at times were given the freedom of a lawn covering several acres for an hour or more at a time. On 16 April, 1912 Dogs 7 and 8 while blind escaped with Dog 6, a normal male of the same litter and chased a half-grown cat together. The latter took refuge in a corner of a porch and was caught and killed by Dog 7. It was not possible in the time left to the experimenter to make a test of the vision of Dog 7, the animal which after the operation seemed most nearly normal. It cannot be ventured how much or how little vision either of these animals had. Inasmuch as their records while blind compare very favorably with that of the normal dogs I have only negative and nconclusive evidence to offer on the question which was the primary object of this investigation. What data I have gathered seem to show only this positive fact: that the dog is capable of learning to make complicated adjustments and of performing a surprising number of "instinctive" reactions perfectly without the aid of vision. This fact remains established no matter what later tests may show regarding the dog's ability to make visual discriminations.

RETENTION

Sixty days after the third problem had been learned by each dog, a test was made of the retention of the learning of the first three boxes. The results are not shown because there was absolutely no significant variation among the records of the different animals. None showed a loss of accuracy of over 10% on the first day's work in the retention test, and in only one case was over three days' work necessary to regain the loss. This exception was Dog 2 on box 1. In learning the problem the an'mal had used first her paw, then her nose, to depress the latch. She settled on the nose-method. In the retention-tests the paw-method reappeared and persisted for six days before the nose-method was completely re-established. The time required for opening the box by either method was about the same—not over one second.

CONTROL TESTS

Two control tests were made on Dogs 1, 2 and 5. The first was for the purpose of observing what disturbance resulted from requiring the dogs to perform their work in total darkness. Two

boxes, which the animals had learned and were then opening in one second or less, were provided with contacts of brass. When the door of the box was closed, a circuit was formed, the current running from the positive pole of a dry battery through the magnet of a Schallhammer in the experimentor's room, to the metal contacts on the door and jamb of the box, to the negative pole of the battery. When the latch of the door was released this circuit was broken and the hammer being drawn from the magnet by a spring gave a signal-click. The animal-room was darkened by heavy black tar-paper nailed over the windows and openings about the door. The tests were made at night and all lights in the animal-room and the room adjoining were put out before the animal was admitted to the experiment-room. Time was taken from the animal's passing between the glass door and the food-box, and the click of the Schallhammer when the box was opened. This is accurate to within one-half second. The blind dogs were slightly disturbed, as is shown by the fact that the time of their first ten reactions varied between four and seven seconds; the next ten averaged about two. Dog 5, normal, was much more disturbed. His first reaction under the changed conditions required thirteen seconds and there were many useless movements. Several times in the first six trials he climbed on top of the box and scratched there. The reactions after the sixth were more definite, and after the twelfth there were no more errors, and the time for each thereafter averaged 1.3 seconds for thirty trials. These results indicate that the light had some stimulating effect, on both the blind and the normal dogs.

The second control was a test on Dogs 1, 2 and 5, of disturbance when a box previously learned by the dog was oriented in another direction. As the boxes stood when the animals were learning them, the latch was always at the northwest corner; when the box was turned 90°, then the latch was on the northeast corner, etc. The following table summarizes the disturbance which follows:

TABLE 7

Disturbance Following Rotation of Problem Box Already Learned

Dog 1. Blind ♀. Box 4

Position of latch-corner of box	Day	No. trials	% Accuracy	Av. time seconds
N.W.	1	10	100	2.2
N. E.	1	10	40	—
"	2	20	80	2.6
"	3	10	100	3.2
S. E.	3	10	20	3.4
"	4	20	60	3.0
"	5	20	100	2.9
"	6	10	100	3.0
S. W.	6	10	00	5.8
"	7	20	40	3.6
"	8	20	80	7.3
"	9	20	90	4.2
"	10	20	100	3.0

Dog 2. Blind ♀. Box 1

Position of latch-corner of box	Day	No. trials	% Accuracy	Av. time seconds
N. W.	1	10	100	1.1
N. E.	1	10	00	11.0
"	2	20	70	4.1
"	3	20	95	2.0
S. E.	4	20	00	6.9
"	5	20	90	3.5
"	6	20	95	2.5
"	7	10	100	2.2
S. W.	7	10	50	2.0
"	8	20	70	3.0
"	9	20	100	2.0

Dog 5. Normal ♂. Box 1

Position of latch-corner of box	Day	No. trials	% Accuracy	Av. time seconds
N. W.	1	10	100	1.0
N. E.	1	10	60	9.1
"	2	20	90	1.0
"	3	10	100	1.0
S. E.	3	10	90	2.0
"	4	20	95	2.5
"	5	10	100	2.0
S. W.	5	10	50	2.6
"	6	20	80	2.0
"	7	20	100	2.0

The animals' behavior in this new situation is interesting. The turning of the box 90° made the problem practically a new one for each dog. Every animal attacked the box at the northwest corner, as if the latch were still there. After the usual methods of "nosing," scratching and biting had failed, the animals resorted to violent random movements, scratching

over the north side of the box, walking around it, barking all the while. Dog 1 required several hours for opening the box the first time. A period of work, which never lasted over ninety seconds, and which averaged near fifteen, would be followed by a prolonged rest. This is characteristic of all my animals' reaction to a new box. After an animal had opened the box once or twice in the new position, the time necessary for opening was quickly shortened and the principal errors made thereafter were those of hesitation or attack at the northwest corner.

Dog 5 surprised the members of the laboratory who ventured to predict his behavior when the box was first turned 90°. The writer expected him to "hunt for the latch." He showed fully as much disturbance as either blind dog. When first admitted to the experiment room he went directly to the northwest corner, scratched violently at the wire over the whole north side, dragged the box, which was heavily weighted, some five inches with his teeth, climbed on top of the box, then lay down to rest after eighty-five seconds of work. He opened the box at the second attack, after accidentally touching the latch with his head. I wish to stress one feature of his behavior. Several times during his periods of effort his head and nose came within an inch of the projecting (lift) latch bar. His actions were not affected in the least by proximity to the latch until he actually *touched* the latch. Then, in less time than is necessary for working a stop-watch lever, he or ented himself to the latch and opened the door by a single movement.

Much less disturbance was shown when the box was turned another 90°. The animals went to the southeast corner after only a few seconds of effort at the northeast corner. At this point the first difference in *method* appeared. Dogs 2 and 3 never changed their customary pathway. They continued to pass to the southeast corner by way of the northwest and northeast corners. Dog 5 went directly to the southeast corner after the seventh trial.

When the box was turned another 90° farther, making the latch corner southwest, Dog 5 went first to the southeast corner and paused long enough to give only one scratch, then hastened to the southwest corner, to which in subsequent trials he went directly. His errors were those of passing too far to the north before orienting himself to the latch, and attacking the latch

too far from the free end to open the box with one effort. The blind dogs at the first trial passed around the box, stopping to scratch at the southeast end, and then trying the southeast and northeast corners before attacking the latch at the southwest. Both learned to stop at the southwest corner during the first series of ten trials: Dog 1 at the third and Dog 2 at the eighth trial.

SUMMARY

The above experiments have shown that it is impracticable to attack the "Molyneux problem" by using dogs rendered temporarily blind by this operation.

It is evident from the records that vision is not necessary to enable the dog to make quite complicated adjustments. The behavior of my animals, particularly that of Dog 5 in the control tests indicates that the dog may make little use of vision. His reaction to the rope and to the disoriented box strengthens the belief that the normal as well as the blind dogs, in ordinary situations rely greatly on kinaesthetic and muscular sense-processes in making their adjustments. This accords with the data accumulated by Watson, Richardson and Vincent in the rat.

The rate and methods of learning in blind and normal dogs shows surprisingly little difference.

Dogs given only ten trials a day required fewer trials for learning, on the average, than those given twenty trials. This fact suggests the question, what is the optimal number of daily trials to educe perfect habits with the least effort?

VITA

I was born 16 May, 1885 at Ridge Prairie, Saline County, Missouri, my parents being Daniel H. and Virginia (Reeder) Johnson. My primary education was received at home and in the public schools; secondary training in the Nelson (Missouri) high school, from which I was graduated in 1900. Following this I spent five years in commercial work and railway (construction) engineering. I was a student in Missouri Valley College in 1905–09, being admitted to the degree of Bachelor of Arts, *magna cum laude*, in 1909. From the year 1909–10 to June, 1912, I was a graduate student in the Johns Hopkins University in psychology, physiology and neurology, with some additional work in philosophy. I was engaged in research work in the University of Chicago during the summer of 1911. I was appointed a fellow of the Johns Hopkins University in June, 1911.

The work in the Johns Hopkins University was done under Professcrs Watson, Dunlap, Meyer, Jennings, Howell, Snyder, Mall, Sabin, Griffin, Lovejoy and Buchner, and Doctor Furry; that in the University of Chicago, under Professors Angell, C. Judson Herrick, and Clark.